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BIOLOGICAL METHODS OF MEASURING THE PROTEIN VALUES OF FEEDS

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THE evaluation of biological methods of measuring the protein values of feeds will be considered under the following headings: 1. The basic facts in protein digestion and metabolism pertinent to the problem; 2. The essentials of the ideal solution; 3. Permissible modifications of these essentials consistent with reasonably satisfactory results; and 4. The limitations of some so-called practical methods.

Since experimental methods in protein digestion and protein metabolism, as they relate to the nutritive evaluation of dietary protein, are concerned with the disposal of nitrogen in the body, the terms "nitrogen" and "protein" will be used interchangeably in the following discussion.

Basic Facts

Digestion. Fecal nitrogen consists of two fractions: nitrogen of dietary origin and nitrogen of body origin. The latter fraction, commonly referred to as the "metabolic nitrogen of the feces," is related to the dry matter consumed for rations of similar roughage content and for intakes of food sufficient in amount to maintain body weight. It is also related, for equal intakes of dry matter, to the indigestible matter contained in the ration. For animals consuming rations low in ballast, such as the rat, dog, pig, and man, the metabolic fecal nitrogen averages about 0.20 to 0.25 gm. per 100 gms. of dry matter consumed. For animals, such as cattle and sheep, that consume rations high in indigestible matter (ballast), the metabolic fecal nitrogen will average about 0.5 to 0.6 gm. per 100 gms. of dry matter consumed.

Because of these facts, in support of which there is ample evidence (Mendel and Fine, 1912; Mitchell, 1924, 1926, 1934; Schneider, 1934, 1935), the true digestibility of nitrogen (protein) is considerably higher than the apparent digestibility, and the latter, for feeds of different kinds, is positively correlated with the protein content of the feed on the dry basis. The importance of the metabolic fecal nitrogen in fixing the value of the apparent digestibility of nitrogen is evident from the closeness of this correlation, represented by a coefficient of 0.76, obtained from Morrison's compilation of digestion coefficients directly determined. Because of this high correlation, the difference between true and apparent digestibility becomes the greater the lower the protein content of the feed on the dry basis. The so-called depressing effect of carbohydrate on the digestibility of protein can apparently be entirely explained on the basis of the enhancement of the excre-

tion of metabolic nitrogen by carbohydrate (Mitchell, 1926).

When feeds are consumed together in a ration, the digestibility of the nitrogen of the mixture often cannot be computed from the digestibility of the individual feeds. This is the result of mutual (or associative) effects on the digestive processes exerted among feeds. These effects, although extreme in magnitude at times, are at present largely unpredictable. Where such effects are appreciable, the digestibility of the nitrogen of a mixture of feeds must be determined directly.

Metabolism. Dietary nitrogen serves two general purposes in the animal body: (1) It maintains the nitrogenous integrity of the tissues, replacing the losses of nitrogen incurred in the endogenous catabolism, and (2) it serves as structural material in the formation of new tissues and secretions in growth, reproduction and lactation. The first function is the predominant component[1] in the maintenance requirement of the body for nitrogen, but the nitrogen thus replaced in the tissues does not contribute to the positive nitrogen balance of the animal. The second function represents the productive requirements for nitrogen, and when it is operating, there is a positive balance of nitrogen, for which it is entirely responsible. It is evident that a consideration of the productive function of protein to the exclusion of the maintenance function in the evaluation of dietary protein leads to an underestimation, which increases in magnitude as the rate of production decreases. Such an error is committed, for example, when food protein is evaluated by expressing the positive nitrogen balance, representing production only, as a percentage of the digestible nitrogen in the ration.

The maintenance requirement for nitrogen varies with the size of animal, and for adult animals of a number of species (Smuts, '35, and literature there cited) is equal to about 2 mgms. of nitrogen per calorie of basal heat. Since the basal heat production varies with the surface area of the animal (or, according to other investigators, with the three-fourths power of the body weight), the maintenance requirement of adult animals varies likewise. It may be presumed that some of the factors that modify the intensity of the basal metabolic rate may also modify the intensity of the endogenous catabolism of nitrogen. On the other hand, immaturity, by exerting a different effect on the endogenous catabolism than on the basal metabolism, disturbs profoundly the ratio of endogenous nitrogen to basal calories, but the nature of the disturbance has not been sufficiently studied to permit its definition here. However, immaturity appears to depress the ratio (Treichler, 1939).

[1] That it is not the only component in the maintenance requirement of nitrogen in the mature animal, follows from the fact that some tissues, especially epidermal tissues and structures, continue to grow throughout life. Hence, true maintenance involves some construction of new protein tissues.

The amino acid requirements for the replacement of endogenous losses of nitrogen in maintenance, for the elaboration of new body tissue, for the production of milk and for the production of eggs may be presumed to differ among themselves. Hence, it may be presumed that the value of dietary nitrogen in meeting these requirements will vary also. But since the amino acid requirements for maintaining the nitrogenous integrity of the tissues are probably simpler than those for the construction of new protein molecules (Burroughs, Burroughs and Mitchell, 1940) and are largely independent of one another as contrasted with the "aggregate" amino acid requirements of growth, it is to be expected that in general the utilization in metabolism of dietary nitrogen will be greater for maintenance than for the productive functions. Obviously the utilization of dietary nitrogen for any productive function cannot be measured separately from the utilization for maintenance, since the nitrogen requirement for maintenance must be satisfied before any type of production can occur. Attempts to estimate indirectly the utilization of dietary nitrogen for some specific function solely, such as milk production, must of necessity neglect the influence on the utilization of nitrogen for maintenance of the increased level of protein nutrition required for production, and also the influence on the utilization of nitrogen for production of the withdrawal from the blood for maintenance purposes of a different assortment of amino acids than that required for protein synthesis, leaving available for the latter purpose an assortment differing from that contained in the original protein supply.

As the concentration of dietary nitrogen is raised from low to high levels, the nitrogen intake will be used for maintenance only, until nitrogen equilibrium is reached, and then, provided there is an ample supply of other required nutrients, it will be used in increasing proportions for whatever productive functions the animal may be capable of, until the limit of productive capacity is reached. Above this level, the nitrogen-containing compounds (the amino acids) resulting from protein digestion will be deaminized, and the non-nitrogenous residue will be used for the production of energy, or for storage as glycogen or fat. However, since the incoming amino acids from the digestive tract cannot be ear-marked for synthesis, and seemingly are not protected against deamination or oxidation, it seems safe to presume that at all levels of intake they will be drawn into the catabolic reactions of the body. The extent of this catabolism will be somewhat in proportion to the concentration of amino acids in the end-products of digestion, and hence somewhat in proportion to the concentration of digestible nitrogen in the digestible organic matter of the ration.

These considerations would lead one to expect that the utilization of absorbed nitrogen for body purposes will be high at very low levels of intake,

i.e., for very wide nutritive ratios, equaling 100 per cent for high quality proteins and conceivably approximating this value even for low quality proteins. As the level of protein increases, the percentage utilization will decrease—the more abruptly, the poorer the biological quality of the protein. Beyond the level that satisfies the nitrogen requirements of the animal completely, a level that will vary inversely with the biological quality of the nitrogen—and may, in fact, never be reached for protein mixtures of very poor quality—the percentage utilization of absorbed nitrogen may be expected to drop abruptly.

From these considerations, it follows that the biological evaluation of dietary nitrogen must be made at levels of protein nutrition that are just adequate to cover the nitrogen requirements of the animal, or, for safety's sake, that are definitely inadequate. The most nearly comparable values will be obtained at levels, differing for each source of dietary nitrogen, that satisfy the same fraction of the total requirements for nitrogen, rather than some fixed level. Ten per cent of digestible corn protein, for example, satisfies a much smaller proportion of the nitrogen requirement of a growing pig than 10 per cent of digestible milk protein. At a 10 per cent level of feeding, the corn proteins may be expected to show up better in comparison with milk proteins than they actually should, because at this level a greater proportion of the corn nitrogen is used for maintenance, possessing the simpler amino acid requirements. The comparison, therefore, might better be made at levels of both proteins that promote the same nitrogen retention on the same intake of food, this retention being either submaximal, or better, maximal at the lowest nitrogen intake capable of promoting maximal retention.

Comparisons of the nutritive values of proteins for maintenance and growth are usually made at levels of protein intake insufficient to promote maximum growth, in order to be able to detect and measure small differences among proteins. At these inadequate levels of protein feeding, the gains in body weight of growing animals will contain varying percentages of nitrogen, correlated positively with the level of protein intake (Forbes, Swift *et al.*, 1935; Forbes, Voris *et al.*, 1938; Mitchell and Hamilton, 1935; Hamilton, 1939). Hence a unit of gain does not possess a constant and definite significance with reference to protein nutrition, while differences in rates of gain on the same level of protein feeding but with different sources of protein do not accurately reflect differences in the nutritive value of the various protein mixtures under test. The inaccuracy in thus measuring protein efficiency by rates of growth is increased if comparable animals are fed their respective rations ad libitum instead of in accordance with a well-considered plan of control.

The study of the nutritive value of the nitrogen of individual feeds is not sufficient to obtain a complete picture of protein nutrition, because the value of a given food in satisfying the nitrogen requirements of animals depends not only upon its own adaptability to these requirements, but also upon its ability to supplement the amino acid deficiencies of other foods with which it may be combined in diets or rations. The biological values of proteins are not necessarily additive. If two proteins or protein mixtures possess the same limiting amino acid, that is, if their biological values can be raised by the same amino acid addition, then they will not supplement each other when combined. Under such conditions, the biological value of the combination, other conditions remaining the same, may be predicted from the biological values of the component proteins. But if two protein mixtures possess different amino acid deficiencies, a supplementing action of some magnitude will always result. In this case, the biological value of the combination will be greater than the mean biological value of the component proteins. The supplementary action may be slight, intermediate or extreme in magnitude, depending on the relative deficiency of the proteins in the first limiting amino acid and upon whether the second limiting amino acid is the same or different for the two protein mixtures. The general effect of the supplementary relations among proteins is to narrow the range of nutritive values for the combined proteins of rations as compared with the values for individual feeds.

The biological value of the nitrogen of feeds in the case of ruminant animals involves to some extent the synthetic activities of the flora and fauna of the paunch. The microörganisms possess the capacity of synthesizing their own cellular proteins from the non-protein nitrogenous constituents of the paunch contents, and of converting feed proteins into cellular proteins through a series of hydrolyses and syntheses. These cellular proteins contained in bacteria, infusoria, yeasts, etc., are then carried through the digestive tract of the animal and digested and utilized in the same manner as are feed proteins. Such symbiotic phenomena can hardly occur to any appreciable extent in animals with a simple digestive system. For these reasons, ruminants are able to utilize the nitrogen of feeds differently than non-ruminants and probably better for those feeds, such as root crops and young forage, containing a large proportion of their nitrogen in non-protein forms.

The calculation of biological values from appropriate nitrogen metabolism data assumes the validity of the distinction, first made by Folin in 1904, between a constant catabolism of nitrogen, related to body size and other body factors, and a variable catabolism of nitrogen, dependent upon the level of protein consumed. The interpretation of these experimental facts by Folin, but not their validity, has been seriously challenged by the recent work of

Schoenheimer and his colleagues, demonstrating clearly a state of dynamic, not static, equilibrium between the tissue proteins and the amino acids of the blood plasma and intercellular fluids. Since it may be concluded by some that the distinction between the two types of nitrogen catabolism made by Folin, upon which the conception of biological values is based, has been entirely swept away by Schoenheimer's findings, as he himself has concluded (Schoenheimer, Ratner and Rittenberg, 1939), the following statement seems in order. There is nothing in Schoenheimer's work that denies the existence of a constant type of catabolism of nitrogen-containing compounds in the tissues; in fact, his beautiful analysis of the creatine-creatinine reaction illustrates this very thing. The term endogenous catabolism is still applicable, since its independence of the protein intake implies its restriction to functional tissue constituents. Also, there is still a variable catabolism of nitrogenous substances, the rate of which is determined by the magnitude of the supply of dietary amino acids, regardless of whether this catabolism involves tissue constituents or dietary amino acids, and regardless of the proportions in which tissue and dietary constituents are involved. While the term exogenous, in its original meaning, is not descriptive of this phase of nitrogen catabolism, it may still be applicable in so far as the speed of the catabolism is set by the magnitude of the exogenous supply of nitrogen.

For these reasons, the theory of protein metabolism upon which the calculation of the biological values of proteins rests is still sound, and hence biological values so calculated still carry their original meaning.

The Ideal Solution

The ideal solution to the problem of the biological determination of the protein values of feeds and rations would seem to involve the following essential features:

1. The measurements of nutritive value selected should be those possessing an absolute, not merely a relative, significance. They should measure, without reference to any other value, the utilization of the protein in the animal body, both in digestion and in metabolism.

2. The measurements of choice should be based upon the unique function of protein in nutrition, namely, to provide the body with nitrogenous compounds for its up-keep and for its productive functioning. The nitrogen balance method, applied under conditions properly selected and controlled, should furnish the desired information. This method necessarily will embrace the non-protein nitrogenous compounds of the food, but there is no good reason for excluding such compounds, since most of the nitrogen they contain, as far as the usual feeds and rations are concerned, contribute to the nitrogenous nourishment of the body. In ruminants, through the mediation

of the microörganisms of the paunch, the non-protein nitrogen of the feed may be converted into protein and digested and utilized as is the true protein nitrogen.

3. The proteins and protein mixtures to be measured should be incorporated into rations that are otherwise nutritively complete.

4. The protein mixtures under test should provide all of the dietary nitrogen. If vitamin supplements are incorporated into the experimental rations, they should furnish as small a proportion of nitrogen as possible. For short experimental feeding periods, it may be advisable to saturate the experimental animals with the water-soluble vitamins in a preliminary feeding period, and to forego the use of such supplements in the periods of experimental feeding. In such a case, the animal body will draw on its stores to correct any corresponding deficiencies in the experimental rations. The use of pure vitamins, rather than vitamin concentrates, would, on the other hand, obviate the need of such an expedient.

5. In order that the biological measurement of protein value possess the most definite significance, and in recognition of the fact that the efficiency of utilization of dietary nitrogen varies with the level of nitrogen feeding, definite levels of feeding must be selected for each type of experiment.

5a. For the purpose of measuring the biological value of dietary nitrogen in maintaining the nitrogenous integrity of the tissues, the ideal level would seem to be that that just supports nitrogen equilibrium. This measurement should be made upon adult animals, the nitrogen nutrition of which, during periods of sexual rest, relates almost entirely to the replacement of endogenous losses.

5b. For the purpose of measuring the biological value of dietary nitrogen in promoting growth, the ideal level would seem to be that that just promotes maximum nitrogen retention. Since this level will vary with the stage of growth of the animal, some agreement must be reached concerning the age and size of animal to use. While it would be well to measure the biological value of dietary nitrogen at various stages of growth in a given species of animal, the selection of some standard age of animal for the comparative measurement of different feeds or rations would lead one to choose the age at which growth is most rapid, corresponding to the point of inflection in the growth curve (Brody, 1927), since this is a definite transitional stage of growth, at which the rate of growth is most rapid. It is, however, a stage of growth that, for a given species of animal, is difficult to determine. Any other choice would necessarily be an arbitrary one, such as the age at which a definite fraction of the mature weight, one-fourth or one-half, is reached. In comparing the ability of animals of different species to utilize for growth and maintenance the same source of dietary nitrogen, it seems evident that

comparative animals should be of equivalent ages in the Brody and others (1925–26) sense of the term.

5c. For the purpose of measuring the biological value of dietary nitrogen in promoting those other types of production (intra-uterine growth, lactation in most animals) also having rates of performance among individual animals sufficiently alike that an average rate can be considered normal for the species, the ideal level of dietary nitrogen would seem to be that which just promotes maximum retention of nitrogen at that stage of the productive function where nitrogen retention is maximal. For the pregnant female this stage of production would be just prior to parturition. For the lactating beef cow, it would be at the peak of her lactation curve.

5d. For the purpose of measuring the biological value of dietary nitrogen in promoting those types of production having rates of performance among individual animals so diverse that no normal rate for the species can be assumed (milk production in dairy cattle, egg production in the domestic fowl), the ideal level of dietary nitrogen would seem to be that which just promotes maximum retention of nitrogen at some definite rate of production, which must of necessity be arbitrarily chosen. For example, in the case of laying hens, the chosen rate of production could be the maximal physiological rate, or a rate that would be average for a flock of hens of good breeding at that season of the year during which the egg production of individual hens is highest.

6. Since dietary nitrogen is lost to the body both in digestion and in metabolism, the efficiency of utilization naturally may be factored into a biological measurement relating to digestion and one relating to metabolism. Obviously, a complete understanding of protein utilization requires a separate determination of these two measurements. The wisdom of this procedure is further supported by the fact that the wastages of dietary nitrogen in digestion are modified differently and by different factors than the wastages of nitrogen in metabolism.

7. The wastages of dietary nitrogen in digestion are contained in the fecal nitrogen excreted, while the wastages in metabolism are contained in the urinary nitrogen excreted. However, both the fecal nitrogen and the urinary nitrogen contain components of body origin as well as of food origin, and the former components are of considerable, and, with food proteins of high utilization, of preponderant importance. Hence, an important item in the biological evaluation of food proteins is the experimental estimation of food and body nitrogen in both feces and urine.

8. The body nitrogen in the feces, the metabolic fecal nitrogen, may be best estimated by measuring the fecal nitrogen of the experimental animals per unit of dry matter consumed of a ration containing no nitrogen but the

same concentration of indigestible ballast as the ration containing the food protein under test. Feces markers should be used for non-ruminant animals.

9. The body nitrogen in the urine, the endogenous nitrogen, may be estimated only by measuring the urinary nitrogen of the experimental animals per unit of body size while consuming a ration containing no nitrogen but otherwise nutritively complete. The unit of body size that serves best as a reference measurement in this connection is the surface area of the animal rather than the body weight (Smuts, 1935; Olson and Palmer, 1940).

10. These two measurements can be made in the same "standardizing period," which should be preceded by a preliminary period on the same ration, of sufficient length that the experimental animals are reduced to an approximately constant output of nitrogen in feces and urine. During the standardizing period the consumption of food should be constant and of sufficient size to prevent any but small losses in body weight. The period should not be continued longer than necessary to obtain measurements of the output of fecal and urinary nitrogen representative of the experimental conditions imposed. Otherwise, fictitiously low values may be obtained, due to the abnormal nutrition prevailing. In comparing the protein values of two rations at comparable levels of feeding, a system of paired feeding may well be used to avoid the possible disturbing effect of differences in the amounts of food eaten by the experimental animals. However, small differences do not seem to exert any appreciable effect.

11. The digestive efficiency of utilization of the dietary protein is measured by the proportion of the intake of nitrogen that is not excreted in the feces. The metabolic efficiency of utilization is measured by the proportion of the truly absorbed dietary nitrogen that is not excreted in the urine. The former is the "coefficient of true digestibility," while the latter is the "biological value" in the sense of Thomas (1909), as adapted to other functions than adult maintenance and as modified and refined by later investigations (Mitchell, 1924; Mitchell and Carman, 1926b). The former value avoids the vitiating effect of body nitrogen excreted in the feces, an excretion somewhat in proportion to the amount of work done in digesting *all* of the nutrients in the ration. The latter value credits the absorbed nitrogen with all of the synthetic processes in the body that it promotes, while it distinguishes between such processes and other syntheses, such as that of fat, to which *all* organic nutrients contribute. Gains in body weight when used as indices of protein utilization do not make this important distinction, since they consist of both protein and fat.

12. It is not advisable to use any experimental animal through a long series of standardizing and test periods, particularly if the test rations contain protein of low biological value. The following succession of periods for

paired growing animals receiving the same amounts of net energy and amounts of the test proteins, A and B, to promote approximately equal nitrogen balances, may be recommended:

Animal 1 A low-N B
Animal 2 B low-N A

or

Animal 1 low-N A B A low-N
Animal 2 low-N B A B low-N

Permissible Modifications

All of the conditions requisite to the ideal solution of the problem of the biological evaluation of the protein components of feeds and rations can be imposed when rats, and some other small laboratory animals, are used as experimental subjects. These conditions can also be readily met with swine, and somewhat less readily with poultry (St. John, Johnson, Carver and Moore, 1932). But with the larger domestic animals and with man, the ideal solution is either impossible, so difficult of realization or so costly as to prohibit or discourage the determination of the true digestibility and the biological value of dietary protein. In such cases, it is possible to relax the rigor of the experimental conditions essential to the ideal solution, or even to dispense with some of the conditions entirely, without impairing seriously the accuracy or the significance of the measurements it is desired to make. What seem to be permissible (in this sense) modifications in these conditions will be listed below.

1. The nitrogen metabolism of the animal affords the clearest picture of protein utilization, while the results of a nitrogen metabolism study relate to a relatively brief period in the life of the animal. The latter point is of importance when the protein requirements of an animal are changing rapidly, as in early growth, necessitating rapid changes in the level of protein feeding if comparable values of protein utilization are to be secured. However, the nitrogen balance itself can be determined satisfactorily also in a properly executed carcass analysis study, although in this case the balance must be measured over a much longer period of time (Mitchell, Burroughs and Beadles, 1936).

2. The nitrogen-free ration used in the standardizing period may well be replaced by a ration containing a small proportion of a protein mixture, such as that of egg or milk, that is utilized in both digestion and metabolism to an approximately complete degree (Mitchell and Carman, 1926b). Small and unavoidable concentrations of protein, not so well utilized as this, may not lead to serious error if their unutilized wastes in either feces or urine or both constitute but a small fraction of the body's own contributions to these

excretions, and if this extraneous protein is present in the test rations as well as in the standardizing ration. Small concentrations of a highly indigestible protein (straw) would also not detract greatly from the significance of the results.

3. If the output of metabolic nitrogen in the feces per unit weight of dry matter consumed of a constant ballast content, and the output of endogenous nitrogen in the urine per unit of body surface have been satisfactorily determined for a given species and found to be sufficiently constant, these contributions of the body to the fecal and urinary nitrogen, respectively, may be estimated in later studies of protein efficiency on the basis of the dry matter consumed and the body surface of the animal.

4. While the distinction between the utilization of nitrogen in digestion and that in metabolism is a useful and an enlightening one, the failure to realize this distinction in a biological determination of the protein value of a feed or ration is not fatal to the significance of the experimental results. The fraction of the total nitrogen of a ration that is utilized by an animal for maintenance and for growth (or other function), provided that the experiment is properly controlled in other respects, is a datum possessing comparative value. It is to be noted, however, that the utilized nitrogen must include the maintenance quota as well as the growth quota, measured by the nitrogen balance, unless the animals receiving the rations being compared are of approximately the same size and may, on all other grounds, be presumed to have the same maintenance requirement of protein.

5. It has been emphasized that the biological value of a protein or protein mixture possesses the unique distinction, among other proposed measures of protein utilization, of possessing an absolute significance, since in itself, and apart from other similar values, it is a quantitative measure of the extent to which the digestible portion of a given source of dietary nitrogen is utilized in the animal functions to which protein alone contributes for the condition under which it was obtained. However, the securing of relative values not possessing this characteristic, if they are secured under properly controlled conditions, is a worth-while scientific achievement. Such values are obtained by taking some protein (casein, for example) or some protein mixture (egg protein or milk protein, for example) as a standard with which to compare all other proteins. In growth experiments, properly controlled, significant measures of over-all protein utilization are provided by the relative nitrogen balances secured for the standard protein and for the proteins with which it is to be compared, using animals of equal weight (and therefore approximately equal maintenance requirements), receiving the same intake of nitrogen (properly chosen), the same intake of energy, and adequate amounts of the other essential nutrients. The nitrogen balances may be measured in metabo-

lism experiments (see Wilgus, Norris and Heuser, 1935), or in properly executed carcass analysis studies. More significant measures of over-all protein utilization would be provided by determining those amounts of nitrogen in standard protein and unmeasured proteins that would induce equal positive nitrogen balances under the above specified conditions.

6. Such relative values as those described under 5 may still possess significance and value, especially in relation to practical nutrition, if the protein sources to be compared are supplements to a standard basal ration, itself containing a concentration of protein that is (necessarily) inadequate for the animal functions under study. Such relative values involve, of course, the supplementary relations existing between the basal proteins and those superimposed upon them. Therefore, they are not comparable with similar values obtained either (a) with the use of another type of protein-containing basal ration, or (b) with the use of a ration free of protein except for the one under test.

The Limitations of Some So-Called Practical Methods

Departures from the conditions of the ideal solution of the problem of the biological evaluation of the proteins of feeds may, if indiscriminately and injudiciously followed, yield results of little accuracy (reproducibility), or of ambiguous significance or both. Possessing no definite interpretation, they are not contributions to the science of nutrition, although they may serve some practical purpose. However, it is a fallacious belief that the less controlled an experiment has been, the more practical its findings become. As a matter of fact, observations secured under uncontrolled conditions are inextricably associated with the particular combination of variable conditions that happened to prevail. Their value in predicting what will happen under another combination of variable conditions cannot be assessed. The use of statistical methods to predict what would have happened if proper experimental control of conditions had been realized is but a poor substitute for such control.

The conditions among those considered to be essential to the ideal solution to the problem, that cannot be relaxed to any considerable extent with impunity seem to be the following:

1. *The measurement of protein utilization by studying the nitrogen economy of the animal.* An alternative measurement that is frequently used in growth studies is body weight gain. However, body weight gain, especially when the food intake is not under control, possesses such a variable chemical composition (Mitchell and Carman, 1926; Mitchell and Beadles, 1930; Mitchell and Hamilton, 1935; Fraps and Carlyle, 1939) that its significance as a measure of protein utilization is dubious. Changes in linear body meas-

urements taken between fixed skeletal points are probably better for this purpose than gains in body weight, but even such measurements have not as yet been calibrated as criteria of protein deposition in the body. The paired-feeding technic involving terminal body length measurements may tell which of two rations is the better for growth, without, however, affording a valid quantitative measurement of the difference. If the test is conducted by varying the intake of protein from the two sources, but not that of other nutrients, until equal gains are secured, the experiment has avoided one difficulty by running into another, that of variable levels of protein feeding. If carcass analysis shows equal deposition of protein as well as equal gains in body weight, the latter difficulty is removed, since the two levels of protein feeding are comparable levels in the sense that they have promoted protein synthesis to the same fraction of the animal's capacity for growth.

2. *The measurement selected must involve the use of dietary protein in maintenance as well as in production.* This point has been emphasized sufficiently in preceding sections to require no extended comment here. Suffice it to say that a gain in body weight, or in body dimension, or in body nitrogen or in the production of milk or eggs does not involve or measure the use of dietary nitrogen in maintaining the body's store of nitrogen. Therefore, it is not a complete measurement of the utilization of dietary protein in the body.

3. *The imposition of comparable levels of protein feeding.* This condition must be controlled in the comparison of different sources of protein, and the type of control must be meticulously and judiciously chosen. Otherwise the comparison possesses no assured validity, either in the scientific or the practical sense, for reasons that have been amply discussed.

4. *The control of the food intake of comparable animals,* which generally means the equalization of food consumption. An insidious fallacy in many "practical" experiments concerned with the biological evaluation of feed proteins is that the food intakes on comparable rations should not be controlled if the true differences among feeds are to be measured, or that it need not be controlled, since the vitiating effect of a variable and uncontrolled intake of protein can be removed by relating gains in body weight secured to the protein consumed. It should take little reflection to convince oneself, first, that ad libitum feeding may grossly exaggerate the difference in nutritive value between two protein mixtures to the extent that the better mixture will be consumed in the greater amount, and, second, that ad libitum feeding may have an unpredictable effect on the measurements made to the extent that the palatability of the test rations, regardless of their protein balance, enters into the picture. The belief that the food-protein cost of body gains is a measure of protein efficiency is demonstrably in error, since the ratio

of dietary protein consumed to gain in body weight secured is closely correlated in positive fashion with the rate of gain itself. Ad libitum feeding has no place in a protein nutrition experiment designed to obtain quantitative data, any more than it is appropriate in digestibility or in metabolism experiments, or in determinations of the net energy value of rations. The palatability of rations, while it is related to their nutritive values, involves other factors that tend to obscure or to distort the significance of gains in body weight or in body nitrogen as measures of the quality of dietary protein. In the purely practical experiment, in which neither the meaning of the results obtained nor their relation to a particular nutrient consumed is a desideratum, ad libitum feeding has a well-established place and cannot be criticized on the above grounds. However, the interpretation of such practical experiments cannot be made in terms of the relative biological qualities of the protein mixtures in the rations being compared.

Literature Cited

Brody, S., C. D. Sparrow and H. H. Kibber. 1925–26. The equivalence of age in mammals estimated on the basis of their growth constants. J. Gen. Physiol., vol. IX, pp. 285–308.

Burroughs, E. W., H. S. Burroughs and H. H. Mitchell. 1940. The amino acids required for the complete replacement of endogenous losses in the adult rat. J. Nutrition, vol. 19, pp. 363–384.

Forbes, E. B., R. W. Swift, A. Black and O. J. Kahlenberg. 1935. The utilization of energy producing nutriment and protein as affected by individual nutrient deficiencies. III. The effects of the plane of protein intake. J. Nutrition, vol. 10, pp. 461–479.

Forbes, E. B., L. Voris, J. W. Bratzler and W. Wainio. 1938. The utilization of energy producing nutriment and protein as affected by the plane of protein intake. J. Nutrition, vol. 15, pp. 285–307.

Fraps, G. S., and E. C. Carylyle. 1939. Relation of gain in weight to gain in energy content of growing chicks. J. Agr. Res., vol. 59, pp. 777–781.

Hamilton, T. S. 1939. The growth, activity and composition of rats fed diets balanced and unbalanced with respect to protein. J. Nutrition, vol. 17, pp. 565–582.

Mendel, L. B., and M. S. Fine. 1912. Studies in nutrition. VI. The utilization of the proteins of extractive-free meat powder; and the origin of fecal nitrogen. J. Biol. Chem., vol. 11, pp. 5–26.

Mitchell, H. H. 1924. A method of determining the biological value of protein. J. Biol. Chem., vol. 58, pp. 873–903.

Mitchell, H. H. 1926. The determination of the protein requirements of animals and of the protein values of farm feeds and rations. Bul. Natl. Res. Council. No. 55, 44 pp.

Mitchell, H. H. 1934. The effect of the proportions of fat and carbohydrate in the diet upon the excretion of metabolic nitrogen in the feces. J. Biol. Chem., vol. 105, pp. 537–546.

Mitchell, H. H., and J. R. Beadles. 1930. The paired-feeding method in nutrition experiments and its application to the problem of cystine deficiencies in food protein. J. Nutrition, vol. 2, pp. 225–243.

Mitchell, H. H., E. W. Burroughs and J. R. Beadles. 1936. The significance and accuracy of biological values of proteins computed from nitrogen metabolism data. J. Nutrition, vol. 11, pp. 257–274.

Mitchell, H. H., and G. G. Carman. 1926a. The composition of the gains in weight and the utilization of food energy in growing rats. Amer. J. Physiol., vol. 76, pp. 398–410.

Mitchell, H. H., and G. G. Carman. 1926b. The biological value of the nitrogen of mixtures of patent white flour and animal foods. J. Biol. Chem., vol. 68, pp. 183–215.

Mitchell, H. H., and T. S. Hamilton. 1935. The balancing of rations with respect to protein. Proc. Amer. Soc. An. Prod., pp. 241–252.

Olson, F. C., and L. S. Palmer. 1940. Comparison of a chemical and biochemical method for determining the biological value of proteins and evaluation of the endogenous nitrogen. J. Agr. Res., vol. 60, pp. 331–342.

Schneider, B. H. 1934. The relationship of the metabolic nitrogen of the faeces to body weight and to food intake of rats. Biochem. J., vol. 28, pp. 360–364.

Schneider, B. H. 1935. The subdivision of the metabolic nitrogen in the feces of the rat, swine, and man. J. Biol. Chem., vol. 109, pp. 249–278.

Schoenheimer, R., S. Ratner and D. Rittenberg. 1939. Studies in protein metabolism. X. The metabolic activity of body proteins investigated with ε(-)-leucine containing two isotopes. J. Biol. Chem., vol. 130, pp. 703–732.

Smuts, D. B. 1935. The relation between the basal metabolism and the endogenous nitrogen metabolism, with particular reference to the estimation of the maintenance requirement of protein. J. Nutrition, vol. 9, pp. 403–433.

St. John, J. L., O. Johnson, J. S. Carver and S. A. Moore. 1932. A method of determining the biological value of protein in the study of avian nutrition. J. Nutrition, vol. 5, pp. 267–276.

Thomas, Karl. 1909. Ueber die biologische Wertigkeit der Stickstoffsubstanzen in verschiedenen Nahrungsmittel. Arch. f. Anat. u. Physiol., Physiol. Abt., 1909, pp. 219–302.

Treichler, R. 1939. Effect of age and other factors on the relationship between basal metabolism and endogenous nitrogen metabolism. Thesis for Ph.D. University of Illinois. 43 pp.+appendix tables.

Wilgus, H. S., Jr., L. C. Norris and G. F. Heuser. 1935. The relative protein efficiency and the relative vitamin G content of common protein supplements used in poultry rations. J. Agr. Res., vol. 51, pp. 383–399.

A PROPOSED SCHEME OF FEEDINGSTUFFS ANALYSIS[1]

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THE scheme of proximate analysis ordinarily used in routine chemical examination of livestock feeds is demonstrably inadequate as an index of their general feeding values. Criticism may be levelled at all five proximate principles but, because of their relative proportions in the feed making up the largest part of livestock rations, the carbohydrate fractions,—crude fibre and nitrogen-free extract,—are of particular interest and importance. In 1938, Crampton and Maynard (1938) proposed that the carbohydrates be partitioned into three fractions, viz., 1) cellulose, 2) lignin, and 3) other carbohydrates. This scheme was believed to be an improvement on the crude fibre—nitrogen-free extract partition as an index of the energy value of feedingstuffs of high lignin content such as pasture herbage. The plan however, was not entirely satisfactory, because of the problems of quantitative lignin determination in materials containing appreciable amounts of protein. In the belief that the lignin—cellulose—"soluble carbohydrate" partition of the total "carbohydrate" component of feeds was sound biologically as an index of this useful energy value, studies have been carried out in this laboratory on an alternate scheme of analysis which would isolate approximately these three fractions, but at the same time avoid the direct lignin determination.

The general plan of the proposed carbohydrate partition is shown in Figure I.

The chemical procedures involved in this system of analyses may be described by steps.

Lipid Extraction. Extraction of the oven dry sample with ethyl ether according to official A.O.A.C. procedure was the first step in the analysis scheme.

Lipid-Free Residue I. This residue was subjected to treatments intended to separate out cellulose and lignin. Treatment with boiling 1% HCl should effectively hydrolyse starches, sugars and most of the hemicelluloses, as well as make soluble a large part of the protein. Digestion with pepsin in N/10 HCl has also been used for removal of protein in pretreatments of feeds for lignin determination. The usefulness of autoclaving to facilitate the hydrolysis of the carbohydrates was also tried out. It appears from the sample figures in Table 1 that the autoclaving was superfluous. Peptic di-

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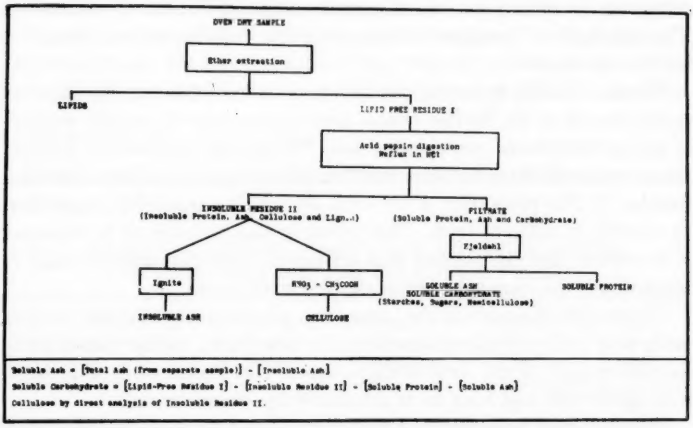

Figure 1. Diagrammatic Scheme of Analysis of Carbohydrate Portion of Feeds.

gestion, however, seemed to be desirable in combination with the hydrolysis with dilute mineral acid. This was more evident in the feeds than in the case of faeces.

TABLE 1.—EFFECT OF VARIOUS TREATMENTS OF THE LIPID-FREE SAMPLE AS SHOWN BY THE WEIGHT OF INSOLUBLE RESIDUE II

Material	Pretreatment Used		
	Autoclaving+acid pepsin digestion +1% HCl digestion	Acid pepsin digestion+1% HCl digestion	1% HCl digestion
	%	%	%
Barley	9.44	9.43	10.62
Pig Faeces	34.11	34.24	34.87

Recovery of the residue by hot filtration through asbestos in a Gooch crucible was facilitated by the use of pre-ignited diatomaceous earth added to the sample prior to filtering. The insoluble material presumably contained chiefly the cellulose, lignin, insoluble protein, and insoluble ash, while the filtrate consisted of the soluble carbohydrates, soluble protein and soluble ash.

Insoluble Residue II. From Insoluble Residue II, two fractions are wanted; viz., cellulose and ash. The cellulose was obtained by procedures proposed by Crampton and Maynard (1938) using boiling nitric-acetic acid for the

digestion. To obtain the ash, a separate sample of Residue II was ashed. This ash figure is necessary in obtaining the "soluble carbohydrates" as will be seen below.

Filtrate. As already noted, the filtrate obtained following the digestion pretreatments of the fat-free sample contained chiefly the soluble portions of the carbohydrates, proteins and ash. The soluble ash content was estimated as the difference between the total ash and that found in the Insoluble Residue II. The proportion of the total ash which was soluble ranged from 35 to 95% in different feeds. This variation was probably to be expected. It is evident that the amount was sufficiently large that account must be taken of it in the estimation of the soluble carbohydrate.

The amount of protein in the filtrate was determined by Kjeldahl analysis, using 6.25 as the N conversion factor. It was found, in the case of feeds, that about 94% of the total nitrogen was in this filtrate while with faeces only about 78% had been made soluble by the pretreatment.

The remaining portion of the filtrate was taken to be the soluble carbohydrate. It certainly contained all of the original starches and sugars. In addition undetermined amounts, but presumably a large proportion, of the hemicelluloses were also put into solution by the HCl treatment. One might expect the hydrolysis of the hemicelluloses to be variable depending on the particular feed or faeces produced from the feed.

Crude Protein, Ash, and "Lignin." From separate samples, total crude protein and total ash were determined by standard A.O.A.C. methods. Thus the proposed plan yields by analytical methods figures for protein, ash, ether extract, soluble carbohydrates, and cellulose; the balance of the material (feed or faeces) is termed lignin.

Scheme of Analysis

Specifically the chemical procedures for the proposed scheme of feed analysis are as follows: extract with ether 3 previously dried 2 gm. samples (1 for ash determination and 2 for cellulose determination of the insoluble residue) according to the standard A.O.A.C. specifications. Transfer the extracted samples to 100 ml. rubber stoppered Erlenmeyers and add to each 50 ml. of an 0.2% pepsin in N/10 HCl solution. Stopper and incubate 12 hours at 40° C., shaking hourly for the first three or four hours. Transfer after peptic digestion to 1000 ml. Erlenmeyers and add to each 250 ml. of an N/.309 HCl solution (this will make a total volume of 300 ml. of a 1% HCl solution) and reflux three hours. Filter while hot through a previously dried and weighed crucible with asbestos mat. Wash with 150 ml. of hot water. Retain the filtrate; make up to 500 ml. and take 100 ml. portions for nitrogen determination, using the standard Kjeldahl method. Dry and weigh

the insoluble residue of the three samples thus treated, ash one, and on the other two, determine cellulose by the method outlined by Crampton and Maynard (1938). On other samples of the original material, total ash and total nitrogen are determined according to standard A.O.A.C. directions.

Composition of Four Cereal Grains

Using the above method of analysis the fractionation of four cereal grains is shown in Table 2.

TABLE 2.—COMPOSITION OF FOUR CEREAL GRAINS BY METHOD PROPOSED. (MOISTURE-FREE BASIS.)

Proximate Principle	No. 3 Feed Barley	Standard Wheat Screenings	No. 1 Feed Oats	No. 3 Feed Oats
	%	%	%	%
Crude Protein (N×6.25)	15.3	14.7	14.8	7.4
Ether Extract	1.6	2.4	3.3	1.9
Ash	2.8	2.1	3.7	5.8
Soluble Carbohydrate	72.1	68.5	62.3	48.0
Cellulose	5.2	5.0	11.2	26.6
"Lignin" (by difference)	3.0	7.3	4.7	10.3

Digestibility Coefficients of the Ration as Fed

In order to test the nutritional significance of these several feed fractions, the faeces produced by four pigs fed these rations were analysed by the above procedures and the digestibility coefficients derived. A figure for Total Digestible Nutrients was also obtained as the sum of the digestible protein, soluble carbohydrates, cellulose, and 2.25 times ether extract.

The average analysis figures and digestibility data of the rations as fed relative to the "carbohydrates" are summarized in Tables 3 and 4. For comparison, data from the scheme originally proposed by Crampton and Maynard and that obtained by the standard A.O.A.C. method are included in the tables.

Discussion

One of the first things to be noted in Table 3 is the comparison according to method of analysis between the amounts of the presumably highly digestible carbohydrate portions, namely nitrogen-free extract vs. "other carbohydrates" vs. "soluble carbohydrates." The nitrogen-free extract is in every case larger than the "other carbohydrates" with "soluble carbohydrates" intermediate. The difference between the two latter lies almost entirely in the difference in apparent lignin. With feeds high in lignin the

new scheme yields figures for "lignin" more in line with published data. The corresponding increase in "soluble carbohydrates" over "other carbohydrates" here is not proportional to difference in digestibility. Indeed, the "soluble carbohydrate" in the poor quality oat ration was actually greater than that of "other carbohydrates."

TABLE 3.—CHEMICAL ANALYSIS OF CARBOHYDRATE FRACTION OF RATIONS BY THREE METHODS OF ANALYSIS

Ration**	Standard Method		Crampton-Maynard Method		Proposed Method	
	Nutrient	Percentage Composition	Nutrient	Percentage Composition	Nutrient	Percentage Composition
No. 3 Feed Barley	N.F.E.*	66	Other CHO*	59	Soluble CHO	63
	Crude Fibre	6	Cellulose	5	Cellulose	5
			Lignin	7	Lignin*	4
No. 1 Wheat Screenings	N.F.E.*	66	Other CHO*	56	Soluble CHO	60
	Crude Fibre	6	Cellulose	5	Cellulose	5
			Lingin	10	Lignin*	8
No. 1 Feed Oats	N.F.E.*	59	Other CHO*	48	Soluble CHO	55
	Crude Fibre	11	Cellulose	11	Cellulose	10
			Lignin	10	Lignin*	6
No. 3 Feed Oats	N.F.E.*	51	Other CHO*	29	Soluble CHO	43
	Crude Fibre	25	Cellulose	26	Cellulose	23
			Lignin	21	Lignin*	10

* By difference.
** Rations were 85% of the basal feed shown plus 15% of a protein-mineral-vitamin supplement.
N.F.E. = Nitrogen-Free Extract.
CHO = Carbohydrate.

Thus it might be argued that the high lignin values obtained by the formaldehyde procedure used in Crampton and Maynard's (1938) plan were in part due to an inclusion of material originating from the hemicellulose component. This material presumably is solubilized during the 1% HCl digestion and hence appears with soluble carbohydrates in the present scheme. Further support is given this theory when the coefficients of digestibility (Table 4) for lignin are examined. These range from 14 to 38% (average 30%) for the formaldehyde lignin against values ranging from −1% to +14% (average 5.5%) for "lignin" obtained by difference under the present proposal. Also the digestibility of "soluble carbohydrate," though not as complete as for "other carbohydrate," is appreciably higher

than for nitrogen-free extract. This is in line with expectation if it can be assumed in the first case that "soluble carbohydrate" contains more hemicellulose than "other carbohydrate" and in the second case, is lignin-free.

In so far as the cellulose is concerned, the new plan results in somewhat smaller values. This again is due to the pretreatment of the sample. The differences are variable, however, and considering the digestibility, are probably insignificant, practically, in feeds of the type involved in this study.

TABLE 4.—DIGESTIBILITY OF CARBOHYDRATE FRACTION OF RATIONS BY THREE METHODS OF CHEMICAL ANALYSIS

Ration*	Standard Method		Crampton-Maynard Method		Proposed Method	
	Nutrient	Percentage Digestibility	Nutrient	Percentage Digestibility	Nutrient	Percentage Digestibility
No. 3 Feed Barley	N.F.E.	80	Other CHO	89	Soluble CHO	83
	Crude Fibre	6	Cellulose	−9	Cellulose	1
			Lignin	35	Lignin	7
	T.D.N.	69	T.D.N.	71	T.D.N.	69
No. 1 Wheat Screenings	N.F.E.	76	Other CHO	86	Soluble CHO	82
	Crude Fibre	6	Cellulose	−2	Cellulose	11
			Lignin	15	Lignin	−1
	T.D.N.	78	T.D.N.	68	T.D.N.	67
No. 1 Feed Oats	N.F.E.	72	Other CHO	80	Soluble CHO	77
	Crude Fibre	12	Cellulose	9	Cellulose	14
			Lignin	39	Lignin	14
	T.D.N.	65	T.D.N.	65	T.D.N.	64
No. 3 Feed Oats	N.F.E.	25	Other CHO	23	Soluble CHO	28
	Crude Fibre	7	Cellulose	4	Cellulose	9
			Lignin	31	Lignin	2
	T.D.N.	26	T.D.N.	26	T.D.N.	23

* Rations were 85% of the basal feed shown plus 15% of a protein-mineral-vitamin supplement.
N.F.E. = Nitrogen-Free Extract.
CHO = Carbohydrate.
T.D.N. = Total Digestible Nutrients.

Total digestible nutrient figures obtained in the case of the present scheme by omitting the lignin from consideration are not appreciably different in the three plans of analysis.

This plan of analysis has been found in our laboratory to be more adaptable for routine work than that previously used involving direct lignin determi-

nations. When applied to feeds typical of those used in pig rations it appears to yield lignin values which are in closer agreement with other published values than were found with the formaldehyde method of lignin determination. It also appears that the fractions isolated are of significantly different digestibility and hence for practical purposes may be used as biological units in the chemical description of the feed.

Literature Cited

Crampton and Maynard. 1938. The relation of cellulose and lignin content to the nutritive value of animal feeds. J. Nutrition, V. 15, No. 4, p. 383–395.

PRODUCTION AND PREVENTION OF BLOAT IN CATTLE ON ALFALFA PASTURE

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IN AN earlier paper (Cole, Mead, and Kleiber, 1942), on the basis of findings which apparently made some previous theories untenable, we postulated that bloat was due to a lack of sufficient irritating or scratchy material in the rumen to induce the reflex act of belching or eructation. We now find, on the basis of the same theory, that bloat can be easily induced and prevented. Furthermore, as we shall show, feeds which initiate eructation likewise initiate rumination, thus giving further evidence that the two reflexes are excited similarly. Schalk and Amadon (1928) submitted evidence that coarse roughage in the rumen served as the normal stimulus for rumination.

Material and Methods

The animals used in this study were purebred Jerseys, Holsteins, and Guernseys. In the lactating group only two Holsteins and two Guernseys were included. Various stages of pregnancy, lactation, and age were represented (table 4). In the non-lactating group, Jerseys and Holsteins were about evenly divided.

Fields with thick stands of immature alfalfa 8 to 14 inches high were selected and tested for their capacity to cause bloat. Cattle bloated in every field. After a field had proved capable of producing bloat, it was used in studying preventive measures. It was tested several times to make certain that the alfalfa had not passed beyond the bloat-producing stage.

Throughout the pasturing periods at least one observer was in the field. Whenever bloat was anticipated, several persons were present or on call in order to remove bloated animals and treat them. Since the cows used were also involved in an inbreeeding experiment, they were usually removed as soon as they were definitely bloated. Despite this precaution, many did bloat seriously. The general policy was deviated from in certain instances by allowing the least valuable animals to remain on pasture until seriously bloated.

The following protocol illustrates the nature of the data recorded:

Cow 766 October 7, 1942 Alfalfa hay fed over night
Alfalfa field no. 6—Height of alfalfa, about 12 inches. Heavy dew this morning. Gentle north wind.

[1] The authors wish to express their appreciation to Mr. Frank Bergthold for his assistance and to Dr. John Britton for his skillful treatment of bloated animals.

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6:58 a.m. Turned on to pasture
6:58 Eating
7:35 Stopped eating
7:42 Eating
8:12 Stopped eating
8:17 Eating
8:29 Stopped eating. Picking along fence
8:42 Stopped picking. Drinking
8:54 Eating
9:00 Appeared full. Still eating
9:27 Stopped eating. Full
9:49 Very full and perhaps slightly bloated.
9:52 Definitely slightly bloated
10:00 Still slightly bloated, but showed no evidence of discomfort.
10:07 Slightly more bloated
10:10 Markedly bloated
10:17 Unchanged
10:23 Unchanged
10:25 Belched
10:37 Still markedly bloated
10:44 Belched
10:45 Defecated
10:46 Belched
10:50 Urinated. Still markedly bloated. Removed from pasture. Continuous observation stopped at this point.
11:20 Still markedly bloated. Dr. Britton inserted a stomach tube, and Dr. Kleiber collected a sample of rumen gas for analysis.
11:40 Stomach tube removed; cow practically normal.

Information on the frequency of defecation and urination was recorded for all animals in preliminary trials, but later only when it might be a clue to discomfort of the bloated animals.

Bloat was detected by visual inspection and by palpation of the triangular area in the left flank. Three degrees were recorded: slight, marked, and severe. In one cow, recorded as markedly bloated, the rumen pressure was determined by connecting a manometer to a canula inserted into the rumen and found to be 20 mm. Hg. "Slight" bloat was never recorded unless gas could be palpated. As will be noted in the protocol, at 9:49 a.m. cow 766 was described as "perhaps slightly bloated." It was not certain whether the distention on her left flank was actually bloat or merely a slight fullness. Had she improved, she would not have been recorded as bloated on this date. A cow was recorded as markedly bloated when she was considerably more than slightly so. Severe bloat always required prompt treatment. Since, in most instances, the cows affected were taken at once from the pasture, our data do not indicate how many animals would have died without precautionary measures. Almost certainly, however, a large percentage of the severe cases would have succumbed.

Results

Production of Bloat. Many studies have been hampered because the investigators were unable to produce bloat at will. In explaining, for instance, why rumen samples were taken from dead rather than living animals, Dougherty (1942) states, "Attempts to produce bloat by feeding methods have met with the same lack of success as has been experienced at other stations." In the studies here reported, every field selected has produced bloat. The period of investigation extended, however, only from August to November, 1942.

TABLE 1.—EFFECT OF CORRAL FEEDING OF HAY AT NIGHT ON THE OCCURRENCE OF BLOAT IN LACTATING COWS PASTURED ON ALFALFA THE FOLLOWING DAY

Date in Oct., 1942	Hay at night	Cows on pasture	Cows bloated	Degree of bloat			Average eating time	Average ruminating time	Total observation period
				Slight	Marked	Severe			
		number	number	number	number	number	minutes	minutes	minutes
6	Alfalfa	16	1	1	0	0	120	18	345
7	Alfalfa	16	3	1	2	0	144	27	393
8	Sudan	17	0	0	0	0	153	37	413
9	Sudan	17	0	0	0	0	141	39	410
10	None	16	1	0	1	0	209	9	403
11	None	15	6	1	2	3	99	0	154
13	Alfalfa	15	0	0	0	0	181	47	425
14	Alfalfa	15	1	1	0	0	143	36	423
15	None	16	5	2	1	2	143	9	404
16	Sudan	16	0	0	0	0	145	69	421
17	None	16	3	1	2	0	170	15	427
18	None	17	10	2	2	6	93	0	139

The extent of bloat is shown in tables 1, 2, and 3. Bloat was most severe when the animals had been deprived of hay for 48 hours. On October 16 for example, the cows had access to Sudan hay until they were turned on pasture at 6:53 a.m. (table 1.) Thereafter, they received no hay until they were taken off pasture on October 18. On the 16th none was bloated; on the 17th three were bloated; on the 18th, 48 hours after the last feeding of hay 10 of 17 were bloated after being on pasture only 2¾ hours. Of these 10, 6 were so severely affected as to require treatment. In our experience no

TABLE 2.—EFFECT OF NIGHT PASTURING OF SUDAN ON THE OCCURRENCE OF BLOAT IN LACTATING COWS PASTURED ON ALFALFA THE FOLLOWING DAY

Date in Oct., 1942	Night pasture	Cows on pasture	Cows bloated	Degree of bloat			Average eating time	Average ruminating time	Total observation period
				Slight	Marked	Severe			
		number	number	number	number	number	minutes	minutes	minutes
24	None	13	6	5	0	1	178	15	420
25	Sudan	13	1	0	1	0	146	69	427
26	Sudan	7	0	0	0	0	198	39	427
27	Sudan	7	0	0	0	0	192	56	425
26	None	6	2	0	0	2	176	12	363
27	None	6	3	1	1	1	202	9	370

cow bloated until she had been on pasture at least 1½ hours; occasionally some did after 7 hours. Of the 42 bloated cows represented in tables 1 and 2, a total of 27 bloated during the first 3½ hours on pasture.

Since other workers have had difficulty in producing bloat at will, a certain factors apparently involved may be of interest:

A thick stand of alfalfa makes possible rapid ingestion. The amount of gas

TABLE 3.—EFFECT OF PASTURE FEEDING OF HAY ON THE OCCURRENCE OF BLOAT IN NON-LACTATING COWS ON ALFALFA PASTURE

Date in November, 1942	Hay on pasture	Cows on pasture	Cows bloated	Degree of bloat		
				Slight	Marked	Severe
		number	number	number	number	number
7	None	28	11	5	6	0
8	Sudan	28	4	4	0	0
9	Sudan	26	1	1	0	0
10	Sudan	26*	0	0	0	0
11	Sudan	26	0	0	0	0
12	None	26	1	0	1	0
13	None	26	4	2	2	0
14	None	26	9	7	1	1

* All but 6 cows remained on pasture continuously from 7:37 A.M. of the 10th to 2:45 P.M. of the 12th. Six particularly valuable cows were taken off pasture these two nights.

formed depends upon the total feed consumed (Cole, Mead, and Kleiber, 1942). If the food is consumed rapidly, one can assume that the cows will have more trouble in expelling the gas as rapidly as it is formed. *Maturity of alfalfa.* For the production of bloat, alfalfa should be pastured in the pre-bloom stage. The crop used in these studies was 8 to 14 inches high; but somewhat earlier stages might be equally or more effective. *Absence of weeds and contaminating grasses.* The tendency of cattle to select considerable amounts of coarse, seemingly unpalatable weeds where succulent alfalfa is abundant was surprising. These weeds or grasses, not only in the field but also along the fence and ditch banks, must be considered. The following incident illustrates the importance of weeds. About 30 dry cows of the college herd were turned on to a thick stand of alfalfa. Certain areas of the field, however, contained considerable knotweed (Polygonum aviculare). No effect was experienced the first week; then several suddenly bloated. A survey showed that the cows had finished cleaning off the knotweed. Apparently this, being coarser than alfalfa, had protected them while it lasted, either because of its physical character or because they ate it instead of consuming larger quantities of alfalfa. Climatological factors were apparently not involved—witness the fact that subsequently this field pro-

duced bloat under a wide range of weather conditions. *Cows should be accustomed to the field.* During the first day or two, cows may wander around investigating and may eat only sporadically. Bloat most often occurs after long-continued eating. *No hay or bedding.* Cows pastured only during the day should not have access to hay or bedding at night. Since feed may remain in the rumen for 60 hours, maximum bloating may not occur until the cows have been deprived of hay for 2 or 3 days. As will be shown later, this time will depend on the nature of the hay. *Dry or lactating cows.* One may logically expect a lactating cow to ingest more feed and thus to be more subject to bloat. This supposition, however, has not been confirmed. Bloat was produced both in dry and in lactating animals. To judge from our evidence bloat in lactating animals is more severe; but the point has never been tested by properly controlled experiments. *Continuous or intermittent pasturing.* Presumably bloat would be more easily produced by pasturing for only a portion of each day, since grazing might thus be concentrated. In most of our experiments we have pastured only in the daytime because field studies of this kind are not easy at night. Since Atkeson, Shaw, and Cave, (1942) have shown, however, that cows pasture more during daylight, the difference may be less than one might suppose. *Individual susceptibility to bloat.* Though our results do not show that age, stage of pregnancy, stage of lactation and milk production have an influence on susceptibility to bloat there are individual differences (table 4). In consequence, anyone interested in producing bloat in order to study preventive measures may well use susceptible animals: presumably, if bloat can be prevented in these, the less susceptible animals will also be protected. *Availability of water in pasture.* In one of our fields water was not available. Although bloat has often been attributed to either the presence or the absence of water, we observed no differences in the extent of bloat which we could ascribe to this factor. Our cows always had free access to water when they were taken off pasture, and very few bloated after that time.

The Value of Sudan or Alfalfa Hay in Controlling Bloat on Alfalfa Pasture. The efficiencies of Sudan and alfalfa hays were first tested by feeding them in the corral to lactating cows the night before pasturing. The cows had access to hay from 2 p.m. to 7 a.m. except when confined in the milking barn for two hours each night and morning. They were usually turned on pasture at about 7 a.m. and removed at 2 p.m. On days when several bloated severely, all were taken off earlier than usual because of lack of facilities and assistance to care for the bloated animals. There were 15 to 17 cows in the experimental group each day; and, for the most part, the same ones were used throughout. At the start of the trial, numbers were painted on their sides in order that the individual animals could be easily recognized at

a distance. Within a few days, however, all could be identified without numbers. One pasture was used during the first 3 days; a second pasture during the remainder of the trial (table 1).

Although the alfalfa hay used was not completely effective as a preventive, it did reduce the incidence and severity of bloat. In an earlier preliminary test, not tabulated, the alfalfa was finer stemmed and still less effective than in this trial. Apparently, therefore, the effectiveness of alfalfa hay in preventing bloat will depend upon its coarse texture.

TABLE 4.—INDIVIDUAL SUSCEPTIBILITY TO BLOAT WITH DATA ON AGE STAGE OF PREGNANCY, STAGE OF LACTATION AND PRODUCTIVE CAPACITY

Cow no.	Number of days observed	Frequency of bloat	Age Yrs. Mos.	Stage of pregnancy*	Stage of lactation*	Av. daily milk production†	2-year-old, 10 months lactation
		days		days	days	lbs.	lbs. B.F.
597	18	3	6–9	6	264	20.2	431
622	18	2	3–9	open	17	29.4	Incomplete
624	17	1	2–8	131	159	18.0	269
722	12	5	5–8	104	255	13.5	443
728	18	1	5–3	70	121	10.3	377
730	18	4	5–3	81	141	22.4	380
736	18	1	5–0	19	105	35.0	521
738	18	6	4–11	open	271	9.2	386
741	15	0	4–8	open	2	29.4	408
749	18	2	4–3	63	98	13.4	308
760	18	5	3–8	4	157	16.5	368
763	18	2	3–6	65	192	13.0	478
766	13	3	3–6	180	217	4.6	429
1003	18	8	8–0	123	300	9.9	488
1041	18	1	3–10	148	184	21.3	407
721	7	0	5–9	open	Fresh 10/13	34.2	507
755	8	0	3–10	open	Fresh 10/11	36.3	596

* Dated from 10-6-42, the first day of the experimental period.
† For the month of October, 1942.

Sudan hay protected the cows completely (table 1). Earlier studies on the feeding habits of cows pastured on Sudan and alfalfa had led us to believe that it might be particularly effective. These preliminary studies showed that lactating cows, if fed leafy alfalfa hay and grain at night and then turned on Sudan pasture for a 7-hour period during the day, spent an average of 70 minutes out of 420 ruminating. When pasturing on alfalfa, however, they spent less than half this time. It is widely recognized that bloat rarely, if ever, occurs in normal animals on Sudan pasture. Apparently both rumination and belching are readily induced by Sudan because of its scabrous leaves.

Sudan hay has an additional advantage in that the lower part of the stem is very woody; it is, furthermore, highly palatable and readily consumed.

Table 1 shows the complete absence of bloat when cows were given free access to Sudan hay the previous night. The hay still had considerable preventive value for 24 hours. For instance, the cows had access to it up to 6:53 a.m. on October 16, when no bloat occurred. On the 17th only 3 of 16 cows bloated, though they had received no hay in the interim. None of these three was seriously bloated; in fact, all were left on pasture until turned out at 2 p.m.

We have previously suggested that belching and rumination are reflex mechanisms excited in a similar manner. If one compares the feeding of Sudan hay with the feeding of no hay, one begins to associate the absence of bloat with a maximum of rumination, a fact indicating that belching and rumination have a common stimulus. The average times spent ruminating over the 7-hour period on no hay, on alfalfa hay, and on Sudan hay were 6½, 32, and 48 minutes respectively. The results with alfalfa hay were rather irregular in that sometimes there was considerable rumination even though some bloat occurred. Results more consistent with our theory were obtained in a preliminary trial with a fine-stemmed alfalfa. In this trial as many as 8 out of 15 bloated, and the cows ruminated about ⅓ as much as on the alfalfa hay used in the experiment summarized in table 1.

Supplemental Sudan Pasture in Controlling Bloat. A preliminary experiment, already mentioned, showed that cows ruminate profusely when on Sudan pasture. If bloat on alfalfa pasture could be prevented by pasturing on Sudan the previous night, this procedure might prove to be economical and labor saving in that harvesting costs would be eliminated. The cows were turned, accordingly, onto Sudan pasture after milking at night and left there until the morning milking, after which they were pastured on alfalfa from 7 a.m. to 2 p.m. The results appear in table 2. Pasturing on Sudan at night completely prevented bloat in cows pastured the following day on alfalfa except for one cow, which bloated on October 25. These cows had not had access to hay or Sudan pasture since October 21, and this one cow (1003) for some reason may not have eaten enough Sudan the first night to be protected. She did not become dangerously bloated, however, and was not taken from pasture until all were removed at 2 p.m. Apparently, therefore, two nights' preliminary pasturing on Sudan will effectively control bloat on alfalfa pasture the third day. Since our data are not extensive, this practice should be inaugurated only with caution.

Feeding Sudan Hay to Cows on Alfalfa Pasture, as a Means of Preventing Bloat. The studies reported above involved lactating cows. For dry cows a better procedure would be to remain on pasture night and day. The ad-

visability of this practice would depend upon whether or not the cows would eat sufficient hay, in preference to pasture, to protect them. The results of feeding Sudan hay on pasture appear in table 3. The pasture was tested for its capacity to induce bloat both at the beginning and at the end of the trial. Except for the two nights indicated in the table the cows were removed from pasture to a dry corral about 3:00 p.m. each day. The following morning they were turned on to pasture, where sufficient baled Sudan was scattered along the fence to provide 8 to 10 pounds per animal. Thus with the exceptions noted, the cows were on pasture for approximately 7 hours each day. The animals used were not the same as in the two previous trials.

On November 7, when no Sudan was given, 11 of 28 cows bloated. On the following day hay was fed, but still 4 bloated. There appears to be an explanation: since these cows had not received hay in this pasture before nor any hay for 48 hours, they consumed considerable pasture before moving over to the hay. They therefore did not consume sufficient hay to protect them this first day. On the next day, November 9, only one cow bloated; and hers was a very light case. In other words, the carry-over effect of hay consumed the previous day is being manifested. On November 10 and 11 no cow bloated. On the 12th no hay was fed, but hay residue in the rumen apparently protected all but one cow, which was slightly bloated. On succeeding days bloat became more common as the amount of hay in the rumen decreased.

Judging from these observations, bloat may occur for a day or two when Sudan hay is fed on pasture if the cows have not had access to hay for several days. Considering this experiment in conjunction with table 1, one may conclude that bloat can be controlled adequately by feeding hay in the pasture if the cows have access to hay the night preceding the first day. There is further evidence to support this view: the practice was successfully followed in the same pasture for about 2 weeks after termination of this trial.

Discussion

On the basis of our theory that bloat results from a lack of sufficient irritating or scratchy material in the rumen to induce the reflex act of belching, we can produce and prevent bloat at will. We have completely controlled it by feeding Sudan hay in the corral overnight and then turning the cows on to alfalfa pasture during the day. Alfalfa hay, particularly if fine stemmed, is less effective in preventing bloat, but is still of definite value. The feeding of Sudan hay to non-lactating cows on alfalfa pasture also appears effective. Though our experiments on Sudan pasture are not extensive, clearly the incidence of bloat on alfalfa pasture can be much reduced by prior pasturing on Sudan.

Not all means of controlling bloat have been considered in this paper. As is generally recognized, for instance, the mixing of grasses with legumes decreases the incidence of bloat. Our studies with Sudan provide a possible explanation. The leaves of all grasses are scabrous and hence induce belching. Probably, however, but few other grasses will prove as effective as Sudan.

The lack of coarse roughage in the rumen is not the sole cause of bloat. Earlier, for instance, (Cole, Mead, and Kleiber, 1942) we showed that belching occurs only when the rumen is in an active state of contraction. Any factor that depresses ruminal motility will interfere with belching and induce bloat. One bloated animal, for example, was stuck with a trocar canula. She subsequently developed peritonitis and bloated even though receiving Sudan pasture or hay and grain. Immotility of the rumen, resulting from peritonitis rather than from lack of roughage, no doubt caused her trouble. Possibly some bloat in calves with digestive disturbances is likewise due to rumen immotility. Thus many causative factors may explain isolated instances. In our opinion, however, bloat on legume pasture is largely due to a lack of sufficient irritating roughage in the rumen.

Other theories have been proposed recently. Jacobsen, Espe, and Cannon (1942) suggest that bloat may be due to physical obstruction of the cardiac orifice by rapid ingestion of legumes. Their studies on the rate of gas production on different feeds confirm our findings; and they, likewise, assume that bloat results simply from inability to expel the gas. Though the evidence at hand does not disprove their theory as to why gas is not expelled, several facts have led us to consider our own opinion more tenable. Many bloated animals can be relieved simply by feeding Sudan hay, though of course the more severely bloated will refuse to eat it. Turpentine also stimulates belching. It is difficult to see how these materials would be effective if we accept the physical obstruction theory.

Dougherty (1941) and Olson (1942) have stressed the importance of toxic gases, particularly hydrogen sulfide. They found a higher percentage of hydrogen sulfide in bloated than in normal cows. In another paper (Kleiber, Cole, and Mead, in press) we have shown that the percentage of hydrogen sulfide is approximately the same in rumen gas of bloated and normal animals. Possibly the discrepancy between results arises from the fact that we took samples of rumen gas from living bloated animals whereas these other investigators, in some instances at least, took samples post mortem.

Summary and Conclusions

Bloat can be produced at will if lactating cows are deprived of hay and bedding for at least 48 hours and pastured on thick stands of immature alfalfa free of weeds and grasses. The animals must be accustomed to the field as they may not eat consistently the first 2 or 3 days. In one instance 10 of

17 cows bloated after 2¾ hours on pasture. Of 17 lactating cows used 14, bloated at least once during the experiments. Some, however, were more subject to bloat than others.

Bloat was effectively controlled on alfalfa pasture by feeding Sudan hay in the corral or in the pasture. The results from feeding alfalfa hay varied greatly, depending upon its coarseness.

Pasturing on Sudan at night before placing the cows on alfalfa pasture, appears to be an effective means of controlling bloat.

Literature Cited

Atkeson, F. W., A. O. Shaw, and H. W. Cave. 1942. Grazing Habits of Dairy Cattle. J. Dairy Sci. 25: 779.

Cole, H. H., S. W. Mead, and Max Kleiber. 1942. Bloat in Cattle. Calif. Agr. Exp. Sta. Bull. 662.

Dougherty, R. W. 1941. Further Investigations of Rumen Gases and Bloat in Ruminants. J.A.V.M.A. 99: 110.

Dougherty, R. W. 1942. Analysis of Gas and Ingesta of Bloated Cattle. Am. J. Vet. Res. 3: 401.

Jacobsen, N. L., D. Espe, and C. Y. Cannon. 1942. Factors Modifying the Rate of Fermentation of Rumen Ingesta and their Possible Relation to Bloat in Dairy Cattle. J. Dairy Sci. 25: 785.

Kleiber, Max, H. H. Cole, and S. W. Mead. 1943. Bloat in Cattle and Composition of Rumen Gases. J. Dairy Sci. In press.

Olson, T. M. 1942. Ruminal Gases in Normal and Bloated Animals. J. Dairy Sci. 25: 684.

Schalk, A. F., and R. S. Amadon. 1928. Physiology of the Ruminant Stomach (bovine). Study of the Dynamic Factors. N. Dak. Agr. Expt. Sta. Bull. 216

BROWN SILAGE FROM ATLAS SORGO—CHEMICAL COMPOSITION, AND APPARENT DIGESTIBILITY AS DETERMINED BY FEEDING TO DAIRY COWS[1]

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SORGHUMS constitute the most important silage crop grown in Kansas, Atlas sorgo being the variety most extensively used. During favorable crop years large quantities of such silage are stored in various types of temporary silos. Frequently, the storage of sorgo in temporary silos results in brown silage, which is characterized by brown to black color caused by excessive heating during storage. Brown sorgo silage probably occurs each year but many more inquiries regarding the value of such silage as livestock feed are received in years when temporary silos are most extensively used.

Review of Literature

Green roughages in general appear to be alike in that heat is generated when they are subjected to natural silage fermentations. Variations in the amount of air in silage may lead to the production of several kinds of silage from the same crop in the same silo. According to Amos and Williams (1922), fermentation temperatures which exceed 113° F. produce sweet, brown silage, while the range of 86 to 99° F. results in light-brown to yellow-brown silage. Babcock and Russell (1900) were among the first workers to conclude that superior silage can be made with lower maximum temperatures of fermentation than preferred by some investigators (Fry, 1883) (Wibberley, 1916).

Heat production in silage is indicative of losses in nutrient value. Reviews of early investigations with corn silage and grass silage (Withycombe and Bradley, 1908), and with maize silage (Woodman, 1925), and later feeding tests with sheep using grass silage (Woodman, 1925a) (Watson, 1931) (Hodgson and Knott, 1937) show that low digestibility of crude protein is the most notable characteristic of excessively heated silage. Woodman and Hanley (1936) reported that sheep digested only 12 per cent of the crude protein in grass silage which had a maximum fermentation temperature of 175° F. They suggested that a considerable part of the reduction in apparent feeding value may have been caused by bacterial conversion of some of the crude protein in the silage to an indigestible, brownish-black, humin-like.

[1] Contribution No. 153, from the Department of Dairy Husbandry.
Contribution No. 279, from the Department of Chemistry.

insoluble substance rich in nitrogen and resembling that removed from the feces of sheep fed excessively heated silage. Silages that have heated excessively may undergo dry matter losses twice as great as those in normal silage with heavy destruction of carotene (anonymous report from N. J. Agr. Exp. Sta., 1939) (Reed, 1939). Brown silage, however, may lose fewer nutrients than normal green silage through drainage from the silo (Woodman and Amos, 1924) The minimum fermentation temperature which causes serious losses in the nutrient value of silage has not been established. McCalmont and Besley (1939) suggested that temperatures below 140° F. are safe. Bender, Tucker, Krueger, Pfau and Fox (1936) noted charring in low-moisture, alfalfa or mixed-grass silage which heated to 160° F. Insufficient moisture in the silage and poor silo-wall construction are two important factors which favor excessive heating of silage.

The general problem of brown silage has received considerable attention in feeding experiments with ruminants. The authors have seen no reports in which the utilization of brown sorgo silage, as reflected by the apparent digestibility, was compared with normal sorgo silage.

Materials and Methods

Typical Field Samples. Three samples of brown silage and one sample of brown high-moisture chopped fodder made from Atlas sorgo were sent to the Kansas Agricultural Experiment Station for analysis. The samples were typical of such brown roughages observed on farms in Kansas, and are described as follows:

I. Sample moderately brown and taken from center of silo. The silo used was of the temporary type, being constructed of baled prairie hay, and was 30 feet in diameter and originally 18 feet high. The crop was harvested for silage in October 1939 before frost and after the seed was mature, and came from a stand having average leafiness with an estimated yie'd per acre of 15 bushels of seed and 5 tons of silage. (Sample received in February 1940 from Beloit, Kans.).

II. Sample black and charred, and taken from the outer portion of the same silo as sample I. Samples I and II were reported equally palatable to cows, but sheep showed a decided preference for sample I.

III. Sample brown and taken from the center of a bundle silo 20 feet in diameter and originally 16 to 18 feet high. The crop originated from part of field of Atlas sorgo which was harvested and ensiled during the previous September. The farmer reported that it was eaten freely by cows but not by young stock. (Sample received in March 1940 from Florence, Kans.).

IV. Sample dark brown to black from same field as sample III, taken from a supply of high-moisture fodder which had been shocked the previous September, and chopped and blown into a stone barn about one month later. The farmer reported that his young stock and the mature cows consumed this feed readily. (Sample received in January 1940 from Florence, Kans.).

Experimental Feeding. Due to a considerable amount of interest in the feeding value of brown sorgo silage, digestion studies were made on the following three experimental silages:

1. Normal green silage, from a wire and roofing paper silo in which the maximum recorded temperature during storage was 92° F.
2. Brown silage, from a sorgo bundle silo in which the maximum recorded temperature during storage was 141° F.
3. Brown silage from a straw bale silo in which the maximum recorded temperature during storage was 147.5° F.

These silages originated from a good-yielding stand of Atlas sorgo on the Kansas State College farm, and were available in conjunction with an investigation of several types of temporary silos. This sorgo was harvested and ensiled during the first week of October 1940 when the crop was considered about ideal in stage of maturity for ensiling purposes. The resulting normal silage was of excellent quality. The two excessively-heated silages were considered moderately brown, with some variations from light-brown to dark-brown from day to day during the digestion trial. Both brown silages would have been considered good feed by many dairymen. The apparent digestibility was determined by feeding each silage to two cows. Each silage was fed simultaneously to a different pair of cows and all three groups of cows received silage exclusively, no other feeds being fed. The digestion trial extended over a 10-day feces-collection period in the early part of March 1941. The trials were preceded by an 11-day adjustment period required to shift the cows from normal herd feeds to rations of Atlas sorgo silage supplemented only with water. The animals employed and the general procedures followed in feeding, sampling for chemical analysis, and weighing of animals were similar to those described by Bechtel, Shaw and Atkeson (1943).

Results and Discussion

Chemical Composition of Silages. The chemical composition of the six sorgo silages and the high-moisture chopped fodder described in this study is summarized in table 1. For comparison, data are included on the average percentage composition of miscellaneous samples of sorgo silage analyzed in

the Chemistry-Department at the Kansas Agricultural Experiment Station during the past six years. All analyses represent Atlas sorgo, the leading silage crop in Kansas.

It would appear that brown sorgo silage is likely to be deficient in, if not devoid of, carotene, judging from the samples analyzed in this study. This may constitute an important limitation in rations otherwise low in vitamin A activity. Carotene was the only constituent, among those listed in table

TABLE 1.—CHEMICAL COMPOSITION OF SOME ATLAS SORGO SILAGES

Description of silage			Moisture	Composition of dry matter*							
Sample no.	Color	Source		Crude protein	Ether extract	Crude fiber	Ash	N-free extract	Ca	P	Carotene
			%	%	%	%	%	%	%	%	mgs. per 100 gms.
I	Brown	Beloit,	66.3	8.6	1.8	27.2	10.1	52.1	0.40	0.18	0
II	Black	Kansas	66.9	10.3	2.3	21.7	12.1	53.8	0.42	0.21	0
III	Brown	Florence,	66.5	7.6	2.0	21.8	8.2	20.2	—	—	0
IV	Brown to black	Kansas	76.5	7.5	2.6	24.0	8.2	57.6	—	—	—
1	Green (normal)	Kansas	73.2	8.7	2.6	25.4	7.2	56.2	0.31	0.17	2.80
2	Brown	State	68.4	8.5	2.5	23.7	7.0	58.3	0.34	0.16	0.13
3	Brown	College	70.2	8.0	2.4	23.8	6.4	59.4	0.26	0.16	0.20
			Average of miscellaneous sorgo silage samples**								
			70.8	9.4	2.4	26.5	8.7	52.6	0.46	0.25	2.88

* Dry matter determined by drying in an oven at 100° to 105° C.

** Data obtained from A. T. Perkins, Department of Chemistry, Kansas Agricultural Experiment Station. The averages represent 59 analyses for moisture, 42 for carotene, 17 for calcium, 16 for phosphorus, and 36 for each of the other constituents.

1, which seemed to be influenced appreciably by excessive heating of sorgo silage.

Digestion Trials. The results of these digestion trials are of special interest in the southwestern states, not only because of the brown silage problem but also because data are included for normal Atlas sorgo, a variety for which no digestion coefficients have been reported. The apparent digestibility of the brown and normal silages differed considerably (table 2). The brown silages were lower than normal silage in digestion coefficients for all constituents except ether extract which was depressed appreciably only in the case of one cow (No. 286). The apparent digestibility of the crude protein fraction was affected most, averaging 56 per cent for normal silage, while the brown silages averaged 23 for the bundle silo and 4 for the straw-bale silo. These results are in general agreement with the literature cited above

and with results obtained from excessively heated alfalfa hay when fed to the same cows (Bechtel, Shaw and Atkeson 1943). The other constituents of the silage were not affected so much, the digestion coefficients for the

TABLE 2.—SUMMARY OF DATA OBTAINED IN DIGESTION TRIALS WITH DAIRY COWS FED RATIONS OF NORMAL AND OF BROWN ATLAS SORGO SILAGE

	Group 1			Group 2			Group 3		
Description of silage Color Maximum recorded temperature (°F.)	Normal-green 92			Brown 141			Brown 147.5		
Cows, herd numbers	K392	402A	Av.	311A	486	Av.	286	K391	Av.
Body weight (lbs.)									
Beginning, preliminary period	1104	763	934	770	930	850	1186	992	1089
Beginning, collection period	1121	761	941	777	866	822	1161	923	1042
End, collection period	1149	711	930	776	852	814	1140	906	1023
Daily milk production[1] (lbs.)	Dry	19.2		Dry	8.1		Dry	14.8	
Daily intake (lbs.[2])									
Silage (on dry matter basis)	20.8[3]	14.5	17.6	11.8[3]	9.5	10.6	10.1	9.5	9.8
Water	24.9	27.4	26.1	9.2	19.7	14.5	18.9	21.8	20.3
Feces voided									
Per day (lbs.[2] of dry matter)	7.5	5.3		4.9	4.4		5.3	4.6	
Moisture (%)	86.3	86.3		81.5	82.3		83.4	82.9	
Composition, dry matter in feces (%)									
Protein	10.3	11.0		15.4	14.6		15.1	15.4	
Ether extract	3.1	3.3		2.5	2.4		3.0	2.5	
Crude fiber	29.1	29.7		27.0	27.9		25.6	29.4	
Ash	12.7	12.5		13.0	12.3		12.8	11.7	
Nitrogen-free extract	44.7	43.7		43.1	42.8		43.6	41.1	
Digestion coefficients[4]									
Dry matter	64	63	64	59	53	56	48	52	50
Crude protein	57	54	55	25	20	23	1	7	4
Ether extract	57	54	55	58	55	56	35	50	43
Crude fiber	58	57	58	53	45	49	44	41	42
Nitrogen-free extract	71	71	71	69	66	68	62	67	64

[1] Expressed as 4% fat-corrected milk (Gaines, 1928) per day during collection period.
[2] Original data recorded in grams.
[3] Small amounts of silage were refused. These were weighed and analyzed to compute net intakes of nutrients.
[4] Averages based on coefficients of individual cows calculated to first decimal.

different constituents for sample 1 (normal silage) and samples 2 and 3 (brown silage) averaged: dry matter—64, 56 and 50; ether-extract—56, 57 and 43; crude fiber—58, 49 and 43; and nitrogen-free extract—71, 68 and 65.

The maximum recorded temperatures of the two brown silages indicate

that damage to sorgo silage may occur when temperatures do not exceed 141° F. Also, the fact that sample 3 having a maximum recorded temperature of 147.5° F. was less digestible than sample 2 having a maximum recorded temperature of 141° F. indicates that an increase of a relatively few degrees, together with the time that the temperature prevails, may have a critical effect on digestibility after an abnormally high maximum temperature is reached.

Palatability, as measured by daily feed intake per unit of body weight, was an important factor contributing to differences in nutrient intake. The cows in group 1 consumed an average of 19 pounds of dry matter from silage per 1000 pounds of body weight, while the cows in group 2 consumed an average of 13 pounds of dry matter from silage and the cows in group 3 averaged 9.5 pounds. The dry matter intake, therefore, was 32 per cent less for silage No. 2 and 50 per cent less for silage No. 3, when each group of cows was fed all the silage they would consume. Thus, excessively heated silage was less palatable than normal silage when used as the sole source of dry matter in the ration.

It is probable, however, that both the digestibility and the palatability of brown sorgo silage varies within rather wide limits, depending upon the severity of heating, and the feeds with which it is fed. Such variations may explain why some investigators report favorably on the palatability of other kinds of excessively heated silage (Hodgson and Knott, 1937) (Watson, 1931 and 1939) while others state that green fruity silage is distinctly superior in palatability to brown silage (Woodman and Amos, 1924).

Dairymen are interested in the productive value of a silage when it is fed in reasonable amounts. When the digestible crude protein was computed for the different silages, sample No. 1 (normal) was found to contain 5 per cent, while sample No. 2 (brown silage) contained 2 per cent and sample No. 3 (brown silage) only contained 0.3 of one per cent. Silage, however, is fed primarily as a source of total digestible nutrients, because of its high carbohydrate content. In this experiment, the computed content of total digestible nutrients for the normal silage was 63 per cent, while sample No. 2 contained 56 per cent and sample No. 3 contained 51 per cent. Thus, compared with normal silage, sample No. 2 (brown silage) contained about one tenth (11 per cent) less total digestible nutrients while sample No. 3 contained about one fifth less (19 per cent) nutrients.

When the digestible nutrient content and palatability of the silages were considered together, it was found that the cows fed normal silage No. 1 consumed 12 pounds of total digestible nutrients daily per 1000 pounds of body weight, while the cows fed brown silage No. 2 consumed 7.3 pounds and the cows fed brown silage No. 3 consumed 4.8 pounds. Thus, the diges-

tible nutrient intake was 39 per cent less for silage No. 2 and 60 per cent less for silage No. 3 when compared with normal silage. The losses in body weights of the different groups of cows support these findings on reductions in digestibility and palatability of brown silage. Should these same relationships prevail when silage is fed with hay and a grain mixture as recommended for dairy cows, the effect of excessive he ting of silage during storage would have a marked influence on the productive value of the ration. Future digestion trials with normal and brown silages made from Atlas sorgo may show different relationships between these silages, particularly if fed with sufficient hay and grain to result in a protein content of the total ration more typical for dairy cows. Even when fed an exclusive silage ration, however, the one dry cow and the one lactating cow fed normal silage in these studies received 155 per cent and 58 per cent, respectively, of their minimum requirements for digestible crude protein per 1000 pounds of body weight. Likewise, the intakes of total digestible nutrients were 165 per cent and 81 per cent, respectively, of their minimal requirements, based on Morrison's feeding standard (Morrison, 1936). The resulting digestion coefficients were similar for the two cows fed normal silage in spite of the fact that the dry cow received considerably more and the lactating cow considerably less digestible crude protein and total digestible nutrients than their calculated requirements. Also, the digestion coefficients for the various constituents of the normal silage compare quite closely with Morrison's estimate for sweet sorgo silage, and are not much different from his data for corn silage considering the fact that results obtained with only two cows are being compared with Morrison's coefficients which represent an average of several trials which undoubtedly showed individual variations. The digestion trials herein reported with rations, admittedly low in protein, typify rations fed by large numbers of Kansas farmers who frequently feed sorgo fodder, sorgo silage and sorgo grain, supplemented with little or no other concentrate feed.

These results were obtained with brown silages which varied from light to dark brown (not charred) and which appeared to be good feed. This is substantiated by the presence of measurable amounts of carotene in the brown silages, since carotene is very unstable and would have been absent if these silages had been sufficiently damaged. Also, the fact that the differences between the two brown silages and the normal silage in ash content were not significant supports the statement that the brown silages appeared to be good feed. Contrarily, field samples I and II which were black to dark brown were much higher than normal in ash content which is in agreement with reports on alfalfa hay damaged from excessive heating (Swanson, Call and Salmon, 1919). Except for carotene content the results of these studies

indicate that the differences in feeding value of excessively heated silages compared with normal silage are not shown by the usual feedingstuffs analyses.

It should be mentioned that the losses discussed pertain only to the feeding value per unit of silage and do not include any losses in weight which may occur in the silo as a result of excessive heating.

Summary and Conclusions

Typical samples of brown Atlas sorgo were described and their origin discussed. Chemical analyses of five samples of brown silage and one sample of high-moisture chopped brown fodder were compared with those for normal green Atlas sorgo silage. Three silages were used in digestion trials conducted with dairy cows fed exclusive silage rations. The apparent digestibility was determined for two brown silages and one normal silage, all of which originated from the same field of Atlas sorgo. The following interpretations of results seem justified:

1. Chemical analyses showed no appreciable differences between the brown and normal silages except for marked differences in carotene, and for differences in ash content among the field samples which appeared to have been more highly heated.

2. Brown sorgo silage was consistently lower than normal green silage in digestion coefficients for all nutrients except ether extract which was lower only in the case of one cow. Protein was most affected, the apparent digestibility averaging 55 per cent for normal silage, 23 per cent and 4 per cent for the two brown silages. Average digestion coefficients for the other constituents of the normal and two brown silages respectively were: dry matter—64, 56 and 50; ether extract—55, 56 and 43; crude fiber—58, 49 and 42; and nitrogen-free extract—71, 68 and 64. The digestion coefficients for normal silage compare favorably with those reported by Morrison (1936) for similar kinds of feed.

3. The degree of reduction of digestibility seems dependent on the temperature to which the silage is heated. Since a reduction occurred at a maximum recorded temperature of 141° F. and marked further reduction occurred at 147.5° F., a relatively few degrees above abnormally high temperatures may have a critical effect on digestibility.

4. Brown silage was less palatable than normal silage, the dry matter intake per 1000 pounds of body weight averaging 19 pounds for normal silage, 13 and 9.5 for brown silages when cows were fed silage exclusively to the limit of their appetites. Thus the reduction in intake was 32 per cent for one brown silage and 50 per cent for the other. The value of these silages as a source of digestible protein is indicated by the average digestible crude protein content of 5 per cent for normal silage, 2 and 0.3 per cent for two

brown silages. The average content of total digestible nutrients was 63 per cent for normal silage, 56 and 51 for brown silages. Thus, the loss in total digestible nutrients for one sample of brown silage was about one tenth, and about one fifth for the other.

5. Differences in palatability together with differences in digestibility indicate that the intake of total digestible nutrients was 39 per cent less than normal silage for one of the brown silages and 60 per cent less for the other.

6. The fact that these results were obtained with brown silages which appeared to be good feed (still containing measurable quantities of carotene) indicates that the usual feedingstuffs analyses fail to show true differences between the feeding value of excessively heated silages and normal silages.

Literature Cited

Amos, A., and G. Williams. 1922. Temperature and Other Factors Affecting the Quality of Silage. Jour. Agr. Sci. 12: 323–336.

Anonymous. 1939. The Effect of Various Ensiling Agents on the Nutritive Value of Field Crops. N. J. Agr. Expt. Sta. 60th Ann. Rept.: 6–7.

Babcock, S. M., and H. L. Russell. 1900. Causes Operative in the Production of Silage. Wis. Agr. Expt. Sta. 17th Ann. Rept.: 123–141.

Bechtel, H. E., A. O. Shaw, and F. W. Atkeson. 1943. Brown Alfalfa Hay—Chemical Composition and Nutritive Value for Dairy Cows. Jour. Dairy Sci., (in press).

Bender, C. B., H. H. Tucker, W. C. Kruger, K. O. Pfau, and A. S. Fox. 1936. Molasses Hay Silage. Jour. Dairy Sci. 19: 137–146.

Fry, G. 1883. Fermentation in Silos. The Agr. Gazette n.s. 17: 196–197.

Gaines, W. L. 1928. The Energy Basis of Measuring Milk Yield in Dairy Cows. Ill. Agr. Expt. Sta. Bul. 308.

Hodgson, R. E., and J. C. Knott. 1937. Stack Silage. Wash. Agr. Expt. Sta. Bul. 348.

McCalmont, J. R., and H. E. Besley. 1939. Silo Pressure and Temperatures with Corn and Grass Silage. Agr. Engin. 20: 227–230.

Morrison, F. B. 1936. Feeds and Feeding. 20th Ed. The Morrison Publishing Company, Ithaca, N. Y.: 975, 977, 1004.

Reed, O. E. 1939. Baled-Straw Silo. U. S. Bur. Dairy Industry Rept. Chief: 14.

Swanson, C. O., L. E. Call and S. C. Salmon. 1919. Losses of Organic Matter in making Brown and Black Alfalfa. Jour. Agr. Res. 18: 299–304.

Watson, S. J. 1931. Digestibility and Feeding Value of Stack Grass Silage. Jour. Agr. Sci. 21: 452–457.

Watson, S. J. 1939. The Science and Practice of Conservation: Grass and Forage crops. The Fertiliser and Feeding Stuffs Jour., London, England. II: 528.

Wibberley, T. 1916. Sweet Stack Silage. Jour. of the Board of Agriculture (Great Britain). 23: 581–583.

Withycombe, J., and C. E. Bradley, 1908. Digestibility of Kale, Vetch Hay, Steamed and Unsteamed Silage. Ore. Agr. Expt. Sta. Bul. 102.

Woodman, H. E. 1925. Digestion Trials with Swine. II. Comparative Determinations of the Digestibility of Dry-Fed Maize, Soaked Maize, Cooked Maize and Flaked Maize. Jour. Agr. Sci. 15: 1–18.

Woodman, H. E. 1925a. The Nutritive Value of a Stack Silage (Rye Grass and Clover). Jour. Agr. Sci. 15: 327–333.

Woodman, H. E., and A. Amos. 1924. Further Investigations into the Changes Which Occur During the Ensiling of a Green Crop. Jour. Agr. Sci. 14: 99–113.

Woodman, H. E., and F. Hanley. 1926. A Study of the Process of Making Stack Silage. Jour. Agr. Sci. 16: 24–50.

FEEDING STANDARD EQUATIONS FOR COWS AND GOATS IN MILK

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General Method

ONE method of deriving a feeding standard is to fit an equation to observations of feed intake on one side, and live weight, yield of product, etc. on the other side. Titus (1928) used the equation method for laying hens; Brody and Procter (1925), for milking cows; Byerly (1941),[2] for laying hens; Crampton and Ashton (1942), for growing-fattening swine.

In the present article the method is used for lactating cows, lactating goats and lactating rats—the latter for comparative purposes. The principle of the method as here applied is to partition the feed intake between working[3] maintenance, milk-energy yield, and gain or loss in live weight. Three somewhat different procedures, designated A, B, or C, are used, depending partly on the nature of the observations.

A. *Composite Method*

Forbes (1935) has published details of an exacting investigation which include by 28-day periods for each of several cows (Holsteins) the feed-energy intake, live weight and milk-energy yield. Direct calcrimetry was used in determination of feed energy and milk energy. From these precision data 107 observations on 10 cows are here selected and fitted with the equation,

$$FE = a_1 W^b + a_2 ME^c + a_3 G + a_4 L \qquad (1)$$

in which FE is daily feed-energy intake in therms (1000 kilocalories), W is live weight in kilograms, ME is daily milk-energy yield in therms, G is daily gain in live weight in kilograms and L is daily loss in live weight in kilograms.[4]

Deming (1938) has developed formulas for the least-squares adjustment of equations of type (1). There are 4 steps: 1) by some means find a close

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[2] Publication includes description of procedure in fitting a power equation.

[3] The term "working" is used in distinction to "idle," in a productive sense. For the present case the nature of the work is the production of milk and working maintenance is more specifically lactating or milking maintenance. Other specific phases of working maintenance are, similarly: growing, gestating, fattening, laying, pulling, etc. The division of total energy metabolism into energy for maintenance, energy for lactation, etc., is not a matter of exclusive separation in the life processes of the animal but rather a matter of convenience in the practical aspects of animal husbandry.

[4] Acknowledgment is made to Dr. Forbes for supplying weekly live weights supplementing his Table 95. These weekly weights have been smoothed by 3-week running averages to derive the present G and L values. For anyone of the 107 observations as here used either G or L is always zero.

approximation of (1); 2) from this approximation derive the residuals; 3) by use of Deming's formulas find corrections; 4) apply the corrections to the approximation. Validity of the procedure depends upon the magnitude of the corrections being not too great.

The first step is carried out by fitting, by least squares, a pilot equation

$$FE = a_1'W + a_1''W^2 + a_2'ME + a_2''ME^2 + a_3''G + a_4'L \qquad (2)$$

and approximating the constants of (1) as:

$$b = 1 + a_1''\overline{W}/(a_1' + a_1''\overline{W}) \qquad (3)$$

$$a_1 = (a_1' + a_1''\overline{W})(\overline{W})^{1-b} \qquad (4)$$

$$c = 1 + a_2''\overline{ME}/(a_2' + a_2''\overline{ME}) \qquad (5)$$

$$a_2 = (a_2' + a_2''\overline{ME})(\overline{ME})^{1-c} \qquad (6)$$

$$a_3 = a_3' \qquad (7)$$

$$a_4 = a_4' \qquad (8)$$

in which the overscore indicates the mean.[5]

Applied to the 107 observations equation (2) yields

$$FE = .068W - (.0000082 \pm .0000198)W^2 + 2.35ME - (.028 \pm .026)ME^2 + 1.7G - 7.7L \qquad (2a)$$

and by use of (2a) and (3)–(8) the approximation

$$FE = .097W^{.934} + 3.01ME^{.837} + 1.7G - 7.7L \qquad (1a)$$

is derived.

In (2a) the standard errors show that the coefficients of W^2 and ME^2 are not significant. An inference is that neither b nor c in (1) differs significantly from unity. This is an important point which may be tested directly by taking $b = c = 1$ in (1), fitting to the 107 observations as step 1, and proceeding with steps 2 and 3. The corrections for b and c turn out to be: b, $-.061 \pm .175$; c, $-.192 \pm .230$. This confirms the inference from (2a), neither b nor c of (1) differs significantly from unity.

The result for step 1, taking $b = c = 1$ in (1) is

$$FE = .0683W + 1.806ME + 1.4G - 7.9L \qquad (1b)$$

The result after completion of steps 2, 3, and 4, with (1a) repeated for comparison is

$$FE = .090W^{.939} + 2.87ME^{.808} + 1.7G - 7.8L \qquad (1c)$$

$$FE = .097W^{.934} + 3.01ME^{.837} + 1.7G - 7.7L \qquad (1a)$$

Equation (1c) is the least-squares adjustment of (1) to the 107 observations, except as it may be invalidated by the magnitude of the corrections in deriving it from (1b). Equation (1c) is not satisfactory in that substitution of mean values ($\overline{W} = 516.3$, $\overline{ME} = 11.58$, $\overline{G} = .24$, $\overline{L} = .19$) gives $FE = 51.4$,

[5] Acknowledgment is made to W. J. English, University of Illinois, for tabulating mchines service, including "interspersed master-card gang punching" of squares of W and ME, which are required in the cards to derive sums of products, W^2W^2 etc. and ME^2ME^2 etc. In the derivation of (3) and (4) it is assumed that a_1W^b and $a_1'W + a_1''W^2$ are equal with respect to slope and partial FE at $\overline{W}$, similarly for (5) and (6). An alternative plan is to assume the two partial regressions equal at two points, say the mean $\pm$ one standard deviation.

whereas the observed $\overline{FE}$ is 55.1. The corresponding substitution in (1a) gives $FE = 55.4$. The corrections of step 3 in deriving (1c) from (1b) are so large, particularly for the ME term, that there is question about the validity of (1c).

It is suggested that equation (2) affords a good first approach in the allocation of daily feed intake between maintenance and daily milk-energy yield. When, as in the present data, it turns out that a_1'' and a_2'' are below the level of statistical significance the problem may be simplified by omitting the terms in W^2 and ME^2, or what is the same thing omitting the exponents b and c in equation (1). If it turns out that a_1'' and a_2'' are not negligible the approximation of (1) through (2)–(8) may be quite sufficient. The exact least-squares adjustment of equation (1) in all its constants simultaneously to observations such as the present ones is not sharply defined, particularly with respect to compensation in a_1 and b or in a_2 and c.

The important point for present purposes is that these 107 precision observations support (or at least do not contradict) the simple postulate that daily feed energy for lactating maintenance is proportional to live weight and daily feed energy for lactation is proportional to daily milk-energy yield.[6]

TABLE 1.—CONSTANTS AND THEIR STANDARD ERRORS FOR EQUATION (9) FOR EACH OF 10 COWS, ARRANGED IN ORDER BY LIVE WEIGHT IN KILOGRAMS, W.

Cow No.	W	Equation constants and standard errors					Deviation*
		K	a_2	a_3	a_4	100K/W	100K/W
12	393	30.1± 4.4	1.64± .37	−4.6± 7.2	−10.3± 2.2	7.66± 1.11	.32± 1.11
10	457	26.5± 2.4	2.08± .25	4.4± 2.7	1.1± 2.9	5.80± .53	−1.54± .53
11	478	40.2± 3.7	1.51± .26	−1.5± 3.1	− 9.4± 4.5	8.41± .77	1.07± .77
9	486	29.8± 16.1	1.90± 1.25	6.9± 7.6	− 1.2± 7.1	6.13± 3.31	−1.21± 3.31
5	500	38.6± 4.5	1.70± .37	−1.6± 3.3	−16.9± 2.9	7.72± .89	.38± .89
8	503	36.1± 3.4	2.13± .30	.2± 2.7	− 9.7± 2.6	7.18± .67	− .16± .67
6	546	36.9± 6.6	1.95± .27	−4.0± 3.6	−19.0± 2.6	6.76± 1.20	− .58± 1.20
3	555	42.4± 3.6	1.19± .35	−2.1± 4.7	− 6.7± 3.4	7.63± .64	.29± .64
7	594	48.1± 7.7	1.15± .52	.8± 5.9	−99.9± 3.6	8.10± 1.29	.76± 1.29
1	639	51.4± 7.1	1.29± .41	−4.1± 2.5	− 6.1± 2.2	8.04± 1.10	.70± 1.10

* Deviation of 100K/W from 7.34, the mean 100K/W.

[6] It will be noted that equation (1a), and others, indicate that unit loss in live weight releases more feed energy than required for the same unit gain in live weight. Obviously there is a fault somewhere in such a result. It seems likely that the G and L values as here used do not adequately represent energy balance of the cow. However, G and L are such minor items, quantitatively, in the allocation of FE that it is safe to say that the faulty outcome with reference to G and L does not invalidate the conclusion that b and c in (1) may be taken as unity. Using nitrogen balance in grams per day, instead of live-weight balance, equation (2) comes out with a coefficient of +.27 for nitrogen gain and −.24 for nitrogen loss. These results indicate that accurate energy-balance data would give acceptable coefficients for gain and loss in equation (2).

B. Individual Method

In the records used above in method A, 7 of the 10 cows each have 11 periods, and the other 3 each have 10 periods. The periods for a given cow are all in the same lactation, the first period starting shortly after calving. In method B the records of each cow are fitted with the equation.

$$FE = K + a_2 ME + a_3 G + a_4 L \tag{9}$$

and the constants with standard errors are given in Table 1.

In (9) K is taken to represent maintenance, FE_1, for the particular cow, although it absorbs all FE not accounted for as a multiple of ME, G or L. Regarding a given cow as constant in weight FE_1 (that is, K) as between cows is related to W by fitting the equation

$$FE_1 = a_1 W^b \tag{10}$$

to the K's and W's of Table 1. The result is

$$FE_1 = .00624 W^{1.394} \tag{10a}$$[7]

By method A lactating maintenance is proportional to $W^{.93}$; by method B, applied to the same observations, it is proportional[8] to $W^{1.39}$. Theoretically method A may be considered preferable. On the other hand, method B conforms more nearly to what is needed in a practical feeding standard since it deals with individual cows through the course of lactation, the daily maintenance requirement of a given cow considered as fixed and the daily lactation requirement considered as proportional to the corresponding daily milk-energy yield.

In general, the results by method B strengthen the conclusion reached by

[7] Equation (10a) is derived by first fitting

$$\log FE_1 = \log a + b \log W \tag{11}$$

to the logarithms of the K's and the logarithms of the W's of Table 1. The result is, $b = 1.267$. Equation (11) is then refitted, weighting by kW^b, that is, any convenient (fixed) multiple of $W^{2.534}$. The second result is, $b = 1.384$, which is so far above the first result that the process is repeated, weighting by $kW^{2.8}$, assuming the least-squares b of (10) to be 1.4. The third result is, $b = 1.394$. The weighting exponent used agrees so closely with this third result that 1.394 may be accepted as the least-squares b of (10).

The least-squares b of (11) may be generally used as a staisfactory estimate of b in (10) but if so used it is not quite proper to say that (10) has been fitted by least squares. (See Deming, revised page 143.)

Another way to approximate b in (10), applied to the K's and W's of Table 1 is to find the linear regression of K on W, and multiply by $\overline{W}/\overline{K}$. This gives, $b = .098(515/38) = 1.328$, a better value (in this case) than the 1.267 of (11).

[8] It is convenient to speak of FE_1 in (10a) as being proportional to $W^{1.39}$ but it must be held in mind that $W^{1.39}$ is not a unit of weight. It may be thought of as a unit of estimated FE_1, that is, feed energy for lactating maintenance estimated by (10a) from live weight of cow.

Along the same line of thought, basal metabolism as between species is found to be proportional to $W^{.73}$, but to call $W^{.73}$ a unit of "active *mass*" or a unit of "physiologic *weight*" or a unit of "metabolic body *size*" seems to be a misuse of the words in italics if not a misconception of underlying principle. If $W^{.73}$ is used as "reference base" it must be understood that the "reference base" is estimated (by the inter-species relation) basal metabolism. $ME/W^{.73}$ is milk energy in terms of estimated basal metabolism, not milk energy in terms of mass, weight or size of animal. As concerns cows in normal daily life basal metabolism cannot be measured if indeed it exists at all. To estimate basal metabolism by an interspecies formula and express ME in terms of units of such an estimate seems a bit remote. In other words, while $ME/W^{.73}$ is clearly defined in a numerical sense its biological definition is not clear.

With regard to principle, the "active mass" sort of concept seems to assume that differences between animals in amount of metabolism per unit time are due entirely to differences in amount of active tissue, ignoring the obvious possibility of differences in metabolic tempo. Metabolic tempo is defined as metabolism per cell per unit time, and practically measured as metabolism per unit live weight per unit time.

method A that lactating maintenance may be considered to be proportional to live weight, or FE_1/W is constant so far as related to live weight. The last column of Table 1 shows, in fact, that FE_1/W deviates significantly from the mean of all 10 cows in only one case (No. 10).

C. *Group Method*

Figure 1 is taken from an article by Gaines (1938b). It presents 666 records of Red Danish cows on farms in Denmark for experimental feeding periods, 10 to 22 weeks in length. The 666 records are divided into two

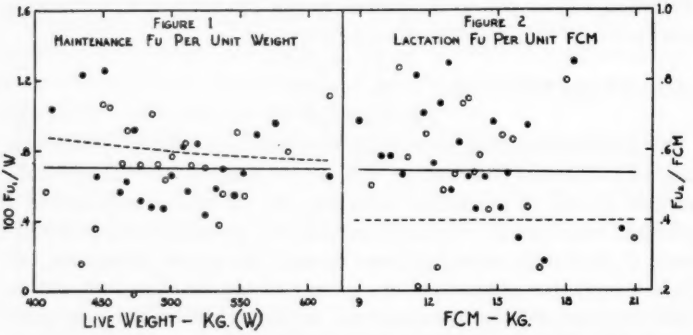

Figure 1. Group records of Red Danish cows. Solid circles signify cows weighing more at close of trial than at start. Open circles signify cows weighing less at close of trial than at start. The solid line is the regression of FU_1/W on W. Its slope is not significant. FU_1/W is independent of W, or FU_1, tends to be proportional to W.

The broken line represents the Danish standard for maintenance, $FU_1 = 1.5 + .005W$. If we take $\overline{W} = 600$ we have $\overline{FU} = 4.5$ and in the form $FU_1 = aW^b$, $b = .005(600/4.5) = \frac{2}{3}$ and $a = 4.5/600^{2/3} = .064$. The circumstantial evidence is that the standard has been formulated on a $\frac{2}{3}$ power concept. The following comparison shows how closely $FU_1 = 1.5 + .005W = A$ and $FU_1 = .064W^{2/3} = B$ agree with each other:

$W = 300$	400	500	600	700	800	900
$A = 3.0$	3.5	4.0	4.5	5.0	5.5	6.0
$B = 2.9$	3.5	4.0	4.5	5.0	5.5	6.0

Figure 2. Same records as figure 1, treated in a similar way, to show the regression of FU_2/FCM on FCM. The solid line represents the regression for all groups taken together. Its slope is not significant. FU_2/FCM is independent of FCM or FU_2 tends to be proportional to FCM.

The broken line represents the Danish standard for lactation, $FU_2 = .4FCM$.

main groups: cows gaining and cows losing in live weight during the experimental period as a whole. Subgroups are formed, each composed of 9 to 23 cows, all cows within a subgroup being of the same live weight within narrow limits. Each subgroup is fitted with the equation

$$FU = K + a_2FCM + a_3G \text{ or } FU = K + a_2FCM + a_4L \qquad (12)$$

in which, for the experimental period: *FU* is daily feed intake in feed units (a feed unit being the equivalent of one kilogram of barley); *FCM* is daily milk-energy yield in kilograms 4 per cent milk;[9] *G* and *L* as before.

In (12) *K* is taken to be feed units for maintenance, FU_1, for the particular subgroup of live weight *W*. Figure 1 shows FU_1/W for each subgroup, plotted against *W*. The regression of the *G* groups has a slight negative slope; that for the *L* groups a slight positive slope; that for both groups together a slight, non-significant, negative slope. It is concluded that lactating maintenance is proportional to live weight in these 666 records of Red Danish cows. Again, in terms of equation (1) *b* may be taken as unity.

Figure 2 carries out a similar comparison using *FCM* subgroups, deriving feed units for lactation, FU_2, and plotting FU_2/FCM against *FCM*. The regressions for both the *G* and *L* groups and the two together have slight, non-significant, negative slopes. It is concluded that feed units for lactation are proportional to *FCM* yield. Again, in terms of equation (1), *c* may be taken as unity.

It will be apparent that in method C differences in milk-energy yield are associated with differences in the cows composing a given group, whereas in method B differences in milk-energy yield are associated with differences in stage of lactation for a given cow. The 666 records used in method C are not published in sufficient detail to use method B; and the records used in method B are too few in number (10 cows) to use method C. Which of the two methods, B or C, is preferable may be a matter of judgment. For the present material the two methods and two sets of data agree in indicating that *b* in (1) may be taken as unity, as does also method A. Methods A and C, applied each to a separate set of data indicate that *c* in (1) may be taken as unity. Obviously method B is not adapted to test the validity of the postulate that *c* of (1) may be taken as unity.

Lactating Maintenance Between and Within Species

Brody (1935) has proposed a "generalized maintenance feeding standard" as applicable to all warm-blooded animals. The standard is $DN_1 = .053W^{.73}$, in which DN_1 is pounds of digestible nutrients per day for maintenance and *W* is live weight in pounds. This equation is of mixed origin. The exponent, .73, comes from a vast body of careful data on basal metabolism of animals ranging in size from mouse to elephant. The coefficient, .053, comes from data on cows in milk, using (not verifying) the exponent, .73.

[9] $FCM = .4 \times \text{milk} + 15 \times \text{fat}$, all in same unit of weight. One kilogram *FCM* = 750 kilocalories milk energy = 34 grams milk protein, regardless of the composition of the natural milk. In the 107 observations used in *A* and *B* the correlation between *ME* and *FCM* is $r = .997$, that is, *FCM* is a valid estimate of milk energy.

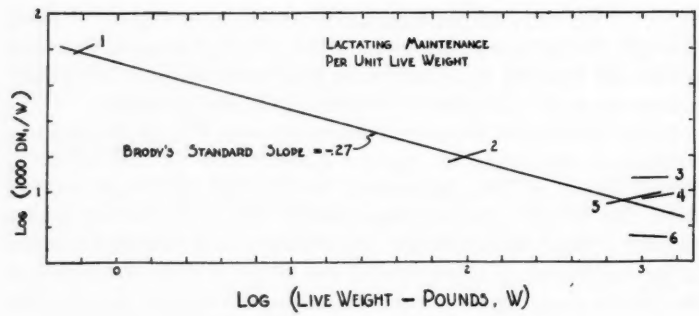

Figure 3. Lactating maintenance per unit live weight between and within species presented in terms of the regression of log (1000 DN_1/W) on log W. The short numbered lines represent the relation within species as follows:

Curve No.	No. Records	Method	Source and Species	Slope
1	126	B	Missouri rats	+.48
	17	B	California goats	+.35
	132	B	Cornell goats	+2.08
2	149	B	Cal. and Cornell goats	+.27
3	107	B	Pennsylvania cows	+.02
4	103	C	Cornell cows	+.13
5	98	C	Minnesota cows	+.14
6	666	C	Danish cows	−.02

Curve 1 is derived from the unique data of Brody and Nisbet (1938). Using their published milk-energy yields (Table A), it comes out that $DN_2 = .15FCM$, and this gives a net efficiency of 125 per cent. Obviously, there is a fault somewhere and it is presumed to be in the estimate of calories per unit weight of milk—the weight of milk being observed but not the composition. For present purposes it is assumed (perhaps rashly) that the actual calorie yields are 1/2 the reported figures. This does not affect curve 1 on the chart at all but does change $DN_2 = .15FCM$ to $DN_2 = .3FCM$.

Curve 2 is derived from data by Voorhies (1917) and by Asdell as embodied in a publication by Brody (1938).

Curve 3 represents the same cows and periods as in equation (10a) but dealing with DN computed from the rations consumed. This accounts for the difference in slope as compared with (10a).

Curves 4 and 5 are derived from data by Haecker and by Harrison *et al.* as embodied in an article by Gaines (1938a). Curves 4 and 5 actually cross each other but are vertically misplaced enough to permit showing the overlapping ends.

Curve 6 represents the same data as in figures 1 and 2, using 1 $FU = 1.72$ pounds DN.

The difference in level of curves 3 and 6 may be associated with differences in surrounding conditions. In curve 3 the cows were subjected to rigorous experimental conditions, excreta harness, ever-present attendants, continuous illumination, etc. In curve, 6 there was a minimum of departure from the normal tranquility of the Danish farm in peacetime. Such a difference of environment may affect the equation allocation of DN between W and FCM.

Figure 3 presents this equation in the form $DN_1/W = .053W^{-.27}$ on a logarithmic scale for a range in size from rat to cow. Figure 3 presents also the regression of log (DN_1/W) on log W as observed within lactating rats, lactating goats, lactating cows. As between species (rat, goat, cow) the results agree with the generalized standard. Within species the relation is sharply different. Within species the slope is positive in 5 of the 6 sets of data given on the graph while the sixth set has a barely perceptible negative slope.

How is the difference between and within species to be explained? DN_1/W may be taken as primarily dependent on and proportional to metabolic tempo (defined in footnote 8) of the animal. The rat has a high metabolic tempo which is a species characteristic, adapted to the average or general live weight of the species and independent of live weight as between individuals within the species. Similarly the cow has a specific metabolic tempo, much lower than that of the rat. On this basis, the observed difference between and within species presented in figure 3 is entirely reasonable.

Kleiber (1932) has given a thorough discussion of the matter. However, Kleiber and Mead (1941), in a critique of the postulate that milk-energy yield tends to be proportional to live weight in highly developed dairy cows,[10] theorize at some length as though a "¾ power" relation between live weight and lactating maintenance, within dairy cows, were an established fact, or foregone conclusion.

While no one of the 6 within-species regressions plotted in figure 3 has a significant slope the fact that 5 of the 6 have a positive slope may raise a question as to whether b in (1) and (10) is not really greater than unity. Such a reality is quite within reason for DN_1 is a sort of statistical average of many life activities in some of which b in the relation $DN_1 = aW^b$ is bound to be greater than unity. For example, when a 1600-pound cow gets to her feet from a lying position she raises her center of gravity roughly 2½ feet; an 800-pound cow, similarly, 2 feet. Such a vertical shift in center of gravity represents in itself 4000 foot pounds of work for the large cow, and 1600 foot pounds for the small cow. Assuming equal efficiency this portion of DN_1 is proportional to $W^{1.32}$.

[10] Essential features of the postulate are that milk-energy yield be measured over a suitable uniform period (such as 8 months) of the lactation and live weight be measured within 31 days after calving of the same lactation. This postulate is not at all in conflict with results presented by Brody (1942) to show that, as between rats, goats and cows, milk-energy yield tends to be proportional to $W^{.71}$. The relation within species is not the same as that between species just as we have seen for lactating maintenance in figure 3.

It is worth noting also, while Brody's data indicate that, per day and per unit live weight, the rat yields 8 times as much milk energy as the cow, on the other hand, per normal lactation or life-time and per unit live weight, the cow yields far more than the rat. Quite likely if some Lilliputian race were to enslave the rat as our race has enslaved the cow, the rat could be developed into a milch animal equal to the cow in terms of milk energy per lactation per unit live weight. In nature milk yield is adapted to the needs of the young, not the demands of a foreign master.

Conclusions

The following feeding standards for cows and goats in milk are justified, in a practical way, from the data entering into figure 3:

$$\text{Cows, } DN = .008W + .3FCM \quad (13)$$

$$\text{Goats, } DN = .016W + .3FCM \quad (14)$$

$$\text{Rats, } DN = .064W + .3FCM \quad (15)$$

in which DN = daily digestible nutrients intake in pounds, W = live weight in pounds, FCM = daily milk-energy yield in pounds 4 per cent milk. The term in W represents DN for maintenance (DN_1) and the term in FCM represents DN for lactation (DN_2).

In these standards DN_2 is a fixed multiple of FCM throughout (see legend of figure 3 about rats). Net efficiency of lactation (milk calories divided by DN_2 calories) is 62.5 per cent throughout.

Within species DN_1 is proportional to W; as between species DN_1 is proportional to $W^{.73}$ (see footnote 8 about meaning of $W^{.73}$).

For the comparatively small range in live weight within species, the numerical distinction between DN_1 proportional to W or proportional to $W^{.73}$ is too small to be of any consequence in estimating feed requirements. As a practical matter, the estimation of DN_1 as in (13) for cows or as in (14) for goats is fully justified.

As a theoretical matter, the observation (figure 3) that DN_1 as between species (cow, goat, rat) is proportional to $W^{.73}$ is interpreted as a species adaptation in metabolic tempo (footnote 8) to the general or average live weight of the species, metabolic tempo within the species (animals of lactating age) being independent of live weight. On this interpretation equations (13) and (14) are justified theoretically (as well as practically).

While the present data justify the theory of (13) for cows so far as concerns DN_1 being proportional to W and DN_2 being proportional to FCM it is not so clear that the coefficients of W and FCM in (13) may not need revision (downward for W and upward for FCM). That can best be settled by fitting the equation $DN = a_1W + a_2FCM$ to a sufficient body of suitable observations representing commercial milk production practice as far as feasible.

Literature Cited

Brody, S. 1935. The Relation Between Feeding Standards and Basal Metabolism. Report of the Conference on Energy Metabolism, National Research Council: 12–23.

Brody, Samuel. 1938. Growth and Development XLIV. Growth, Milk Production, Energy Metabolism and Energetic Efficiency of Milk Production in Goats. Mo. Agr. Exp. Sta. Res. Bul. 291.

Brody, Samuel. 1942. Lactational Performance and Body Weight. Science, 95: 485–486.

Brody, Samuel and Nisbet, Ruth. 1938. Growth and Development XLVII. A Comparison of the Amounts and Energetic Efficiencies of Milk Production in Rat and Dairy Cow. Mo. Agr. Exp. Sta. Res. Bul. 285.

Brody, Samuel and Procter, Robert C. 1935. Growth and Development XXXV. Energetic Efficiency of Milk Production and the Influence of Body Weight Thereon. Mo. Agr. Exp. Sta. Res. Bul. 222.

Byerly, T. C. 1941. Feed and Other Costs of Producing Market Eggs. Md. Agr. Exp. Sta. Tech. Bul. A 1.

Crampton, E. W., and G. C. Ashton. 1942. The Feed Requirements of Market Hogs. A Tentative Feeding Standard. Sci. Agr. 22: 390–400.

Deming, W. Edwards. 1938. Some Notes on Least Squares. U. S. Dept. Agr.

Forbes, Ernest B. 1935. The Mineral Requirements of Milk Production. Pa. Agr. Expt. Sta. Bul. 319.

Gaines, W. L. 1938a. Nutrients for Lactation, Working Maintenance, and Gain in Live Weight in American Dairy Cows. Jour. Dairy Sci., 21: 585–592.

Gaines, W. L. 1938b. Feed Units for Lactation, Working Maintenance and Gain in Live Weight in Danish Dairy Cows. Jour. Dairy Sci., 21: 645–650.

Kleiber, Max. 1932. Body Size and Metabolism. Hilgardia, 6: 315–353.

Kleiber, Max, and S. W. Mead. 1941. Body Size and Milk Production. Jour. Dairy Sci., 24: 127–134.

Titus, H. W. 1928. The Gross Maintenance Requirements of White Leghorns. Poultry Sci.. 8: 80–84.

Voorhies, Edwin C. 1917. The Milch Goat in California. Cal. Agr. Exp. Sta. Bul. 285.

CATTLE GRAZING EXPERIMENTS WITH SERICEA LESPEDEZA[1] AT BELTSVILLE, MARYLAND

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SERICEA LESPEDEZA, *L. cuneata* (Dum. de Cours) G. Don, is recognized as a valuable legume for erosion control and improvement of acid soils in the southeastern part of the United States. In addition, this perennial plant may produce relatively high yields of easily cured forage on the infertile highly acid soils of that region.

Only general observations are available as to the value of this plant for pasture. Results of feeding trials with sericea hay, however, have been reported by Mooers and Ogden (5) of Tennessee, Helm and Etheridge (3) of Missouri, Grinnells of North Carolina (2), Holdaway *et al.* (4) of Virginia, and others. While the results reported by these investigators are somewhat contradictory, they indicate that sericea hay is inferior to alfalfa hay, the variance in results being attributed largely to differences in the quality of the hay used in the tests, due to stage of cutting or method of handling. In a 98-day wintering experiment, comparing sericea lespedeza hay with alfalfa, at the U. S. Department of Agriculture Beltsville Research Center, Beltsville, Md., carried on between the Bureaus of Plant Industry, Soils, and Agricultural Engineering and Animal Industry, ten 610-pound high quality steers gained 61 pounds a head on an average ration of 20 pounds of sericea, whereas eleven similar steers averaging 601 pounds gained 134 pounds a head when fed alfalfa hay at the rate of 19.7 pounds a head daily.

The object of the investigations herein reported was to determine the value of sericea lespedeza as a grazing plant for beef steers. The investigations were conducted jointly by the Division of Forage Crops and Diseases of the Bureau of Plant Industry, Soils, and Agricultural Engineering and the Animal Husbandry Division of the Bureau of Animal Industry of the U. S. Department of Agriculture at Beltsville, Maryland.

Plan of Work

The experiment as planned consisted of a comparison of the productivity in terms of animal gains on three pastures, (1) a 10 acre field of permanent pasture (mostly grass), (2) ten acres of sericea lespedeza, and (3) a pasture

[1] Presented at the annual meeting of the American Society of Animal Production, at Chicago, Illinois, December 2, 1942.

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composed of five acres of the permanent pasture (mostly grass) and five acres of sericea lespedeza.

The pastures were established on a relatively infertile acid sand to sandy loam soil of the Evesboro soil series. The 15-acre sericea lespedeza pasture used in this experiment was seeded on a prepared seedbed in June, 1934. Three hundred pounds of 16 per cent superphosphate per acre was applied to the area at the time of seeding. The area was cut for hay during the years 1935 through 1938. An excellent stand of sericea has been maintained throughout 1939, 1940 and 1941.

The permanent pasture was located on a 15-acre tract near the field of sericea. This area, plowed in July 1938, received at that time two tons of ground limestone and 400 pounds of a 3–12–4 fertilizer per acre. The seedbed was prepared and a permanent pasture mixture composed of 24 per cent each of Kentucky bluegrass, Canada bluegrass, and orchard grass, 12 per cent timothy, 6 per cent redtop, and 10 per cent White Dutch clover was seeded on August 31, at the rate of 34 pounds per acre. Satisfactory stands were secured over the area as a whole. A mixture of Korean and common lespedeza (1:1) was broadcast over the pasture at the rate of 15 pounds per acre on March 20, 1939. After the first year, a good mixture of the sown species had become established.

Each pasture was divided into 5 and 10 acre tracts. The two 5-acre pastures were connected by a lane. Water and salt were provided in all pastures.

Herbage yields were determined from 10 wire cages, 4×4 feet in size, in each pasture. The herbage under the cage was harvested to simulate the adjoining grazed area at 28-day periods. The cages were moved to a new location in the pasture after each harvest. Herbage yields are expressed in pounds per acre of oven-dry material.

A group of Hereford steers, yearlings in 1939, from the U. S. Range Livestock Experiment Station at Miles City, Montana, was used the first three grazing seasons, 1939, 1940 and 1941. Yearling Hereford steers, Oklahoma grown, grazed the pastures in 1942. Each year the steers were weighed on three consecutive days at the beginning and at the close of the grazing season and weighed at 14- or 28-day intervals while the steers were on pasture. Each year the steers were turned on the pasture when the new shoots of sericea had reached a height of 4 to 6 inches, usually about May 15.

Results

1939: Grazing began May 18 and ended October 19. Pastures were grazed at the rate of one animal to two acres of pasture. During the grazing season the permanent pasture produced 116 pounds of beef per acre as compared to a loss of .7 pound on sericea. The yearling steers refused to graze the

sericea at the start and only spot grazed a few small areas during the latter half of the season. During the early half of the season the steers grazed the few weeds and weedy grasses which had persisted in the sericea and completely defoliated the several species of low-growing hardwoods, predominately oaks, along the fence rows. Of the steers in the sericea pasture, one steer died on September 4, while another died within a few days after the season closed. These losses have not been included in the loss of .7 pound for the sericea pasture.

TABLE 1.—AVERAGE PRODUCTION OF HERBAGE FROM SERICEA LESPEDEZA AND PERMANENT PASTURE, 1940 AND 1941, AT BELTSVILLE, MARYLAND

Pasture	Dry herbage—pounds per acre						
	May 15 to June 12	June 12 to July 10	July 10 to Aug. 7	Aug. 7 to Sept. 4	Sept. 4 to Oct. 2	Oct. 6 to Oct. 16	Total
Permanent pasture	204	150	177	207	128	35	901
Sericea lespedeza	225	539	522	559	176	78	2099

1940–41: The results obtained the two years 1940–41 were very similar. The grazing seasons in both years began May 15 and ended October 16. The permanent pastures were medium to closely grazed. The 10-acre sericea pasture was exceptionally well grazed during the first half of the grazing seasons, being uniformly grazed to a height of 6 to 8 inches. During this period the sericea within the cages was from 4 to 8 inches taller than the grazed plants. Herbage yields in pounds per acre for the two years are given in table 1. There was little doubt that relatively large amounts of sericea had been consumed by the steers. Attention is called to the relatively high yields of sericea from June 12 to September 4. The extent of the grazing on sericea however, declined as the season advanced, grazing being light in September and October.

The average production in pounds of beef per acre for the two years, 1940 and 1941, table 2, was 104 pounds for permanent pasture, and 43 pounds for the sericea lespedeza. The gains on permanent pasture were the best during the first, fourth, and fifth grazing periods. The steers on sericea made small gains the first 28-day period, lost weight the second period, but made good gains during the third period, July 10 to August 7. The steers maintained their weight through August but began losing weight in September and October.

Steers on the 5 acres of permanent pasture and 5 acres of sericea grazed the sericea sparingly. Since gains made by this lot of steers are attributed to

the five-acre permanent pasture, for reasons of brevity the results will not be discussed here.

Herbage samples harvested from cages in the pastures were analyzed for ash, ether extract, crude fiber, crude protein, nitrogen-free extract, calcium, and phosphorus.[3] The composite analyses of the samples of 1940 and 1941, table 3, show very low ash and phosphorus in sericea as compared to the permanent pasture herbage. The low ash content of the sericea herbage suggested the possibility of improving the gains on sericea through the use of mineral supplements. Previous records had shown that steers on sericea consumed appreciably more salt than those on permanent pasture.

TABLE 2.—PRODUCTION OF BEEF FROM SERICEA LESPEDEZA AND FROM PERMANENT PASTURE AT BELTSVILLE, MARYLAND, 1939, 1940 & 1941.

Grazing Season	Beef production—pounds per acre						
	May 15 to June 12	June 12 to July 10	July 10 to Aug. 7	Aug. 7 to Sept. 4	Sept. 4 to Oct. 2	Oct. 2 to Oct. 16	Total
			Permanent Pasture				
1939[1]	26.2	14.1	34.9	15.6	16.5	8.4	115.7
1940–41[2]	38.4	13.5	12.1	26.5	24.1	−11.0	103.6
			Sericea Lespedeza Pasture				
1939[1]	5.5	2.6	4.1	−14.8	5.2	−3.3	−.7
1940–41[2]	9.5	−3.9	49.4	1.7	−4.8	−8.7	43.2

[1] The same group of steers, yearlings in 1939, were used the first three years, 1939, 1940 and 1941.
[2] Two year average.

In August 1941, mineral boxes, protected from the weather, were provided in all pastures. Equal amounts of the two mineral supplements, (1) Florida mixture (composed of 100 pounds by weight of salt, 25 pounds of iron oxide (Fe_2O_3) and one pound of copper sulphate), and (2) a 1:4 mixture of salt and disodium-phosphate were made available to the animals. The steers on permanent pasture refused the mineral supplements, while those on the sericea pasture ate sparingly of the Florida mixture but eagerly ate all of the disodium-phosphate-salt mixture in a short time. Unfortunately, sufficient disodium-phosphate could not be obtained to last throughout the grazing season.

Clarke, Frey, and Hyland (1) have stressed the possibility that the high tannin content of sericea is responsible for the low palatability of this species. To secure information on this possibility, herbage samples collected in 1940

[3] Samples of herbage analyzed by H. L. Wilkins of the Division of Forage Crops and Diseases, Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture.

were analyzed for total tannin.[4] The samples collected June 12 and July 8 were low in tannin, 4.2 and 5.5 per cent, respectively, the sample collected August 7, contained 8.6 per cent tannin, while those collected September 3, October 3, and October 15, contained 7.3, 9.0, and 6.3 per cent, respectively. Since the gains of the steers were low the first and second weight periods and exceptionally high on the August 7 weighing, it seems hardly probable that tannin is the only factor affecting palatability in this species.

1942: Owing to the exceptional gains made by steers on sericea pasture from July 10 to August 7, of 1940 and 1941, a period when permanent pas-

TABLE 3.—CHEMICAL COMPOSITION OF HERBAGE FROM PERMANENT PASTURE AND SERICEA LESPEDEZA, 1940 AND 1941

Pasture	Percentage composition—moisture free basis						
	Ash	Ether extract	Crude fiber	Crude protein	N. free extract	Ca.	P.
			1940				
Permanent pasture	9.50	3.46	26.21	12.92	47.90	.62	.38
Sericea lespedeza	4.28	1.97	23.11	16.82	53.81	1.19	.22
			1941				
Permanent pasture	8.43	3.40	25.27	11.46	51.44	.66	.41
Sericea lespedeza	4.32	2.14	23.26	16.43	53.86	1.02	.23

tures are usually least productive, the experiment was modified in 1942 to determine if sericea pasture could be used to supplement permanent pasture during mid-summer. Sixteen steers were allotted at random to two lots of 8 steers each. Only the 10-acre permanent pasture and the 10-acre sericea pasture were used in the beginning of this test.

The two lots of steers were turned on to the pastures May 14, 1942. The same mineral supplements as used in August 1941, were available to the animals all season. At the end of six weeks' grazing, June 25, half of the steers of each pasture were interchanged, four going from the sericea to permanent pasture and vice versa.

Total production on permanent pasture, table 4, was lower than previous years, steers producing only 72 pounds of beef per acre. Sericea lespedeza was only lightly grazed by the yearling steers. Final weights on September 3 showed that steers which had been on sericea all season had lost an average of 14 pounds each, or a loss of 16 pounds per acre. The four steers changed from the permanent pasture to sericea on June 25 lost an average of 77 pounds

[4] Analyses of tannin made by I. D. Clarke, Bureau of Agricultural and Industrial Chemistry, U. S. Department of Agriculture, Washington, D. C.

per steer the first 28 days, gained back 31 pounds the next 28 days, but lost 13 additional pounds from August 20 to September 3. In contrast to the above, the four steers changed from sericea to permanent pasture gained an average of 55 and 56 pounds per steer for the first and second 28 day periods following the change of pasture.

The one-year results indicate that steers will not gain in weight following a change from a permanent pasture to a pure stand of sericea lespedeza in mid-summer.

TABLE 4.—PRODUCTION OF BEEF FROM SERICEA LESPEDEZA AND FROM PERMANENT PASTURE, 1942

Grazing period	Pounds of beef per acre[1]			
	Permanent pasture[2]	Sericea lespedeza[2]	Production from interchanged steers	
			Sericea to permanent pasture	Permanent pasture to sericea
May 14–28	18	14		
May 28–June 11	16	−4		
June 11–25	6	−28		
June 25–July 9	14	9	31	−25
July 9–23	5	−24	12	−36
July 23–Aug. 6	−12	11	10	5
Aug. 6–20	33	11	35	20
Aug. 20–Sept. 3	−8	−6	0	−10
Production, 5/14–6/25	40	−17		
Production, 6/25–9/3	32	1	89	−47
Total production	72	−16	—	—

[1] Half of the steers were interchanged on each pasture June 25, 1942.
[2] Production based on 8 steers to June 25, four steers after that date.

The difference in the total consumption of minerals by the two lots is very striking. The eight steers on permanent pasture consumed approximately 11 pounds of the salt-disodium-phosphate mixture, 7 pounds of the Florida mixture and 22 pounds of salt and the steers on sericea consumed about 50 pounds of the first mixture, 10 pounds of the second, and 38 pounds of salt. These results along with those of 1941 indicate that sericea may be deficient in one or more essential minerals.

Summary and Conclusions

The results of four years' grazing of sericea lespedeza with beef steers show that this forage by itself is not a satisfactory grazing crop.

Yearling steers in 1939 spot grazed small areas in the 10-acre field of sericea and in 1942 grazed the field more generally but not closely at any time during the season. The yearling steers failed to graze the sericea satisfactorily, or make reasonable gains at any time. In contrast, however, the two- and three-year old steers in 1940 and 1941 ate the forage readily, particularly the first three months of the grazing seasons. Good gains, however, were secured with these more mature animals only during July and early August.

Steers on sericea consistently consumed more salt than those on permanent pasture. Chemical analyses of herbage samples from the pastures revealed a low content of total ash and phosphorus in the sericea lespedeza herbage. The feeding of mineral supplements in 1942 did not contribute to increased steer gains. Steers on the sericea lespedeza pasture consumed approximately 6.2 pounds of disodium-phosphate per head during the season as compared to 1.3 pounds for those on permanent pasture. The results indicate that sericea is either lacking in nutrients essential to satisfactory gains of cattle or contains some inhibiting material.

The tannin content of sericea as affecting palatability and animal gains was not at all positive in this experiment. Analyses of the 1940 samples indicated a general increase in tannin as the season advanced.

Additional investigations have been planned to secure information on the value of sericea lespedeza in association with some of the improved grasses for pasture.

Literature Cited

(1) Clarke, I. D., R. W. Frey, and H. L. Hyland. 1939. Seasonal Variation in Tannin Content of Lespedeza sericea. Journal of Agricultural Research, Vol. 58. 131–139.

(2) Grinnells, C. D. 1935. A Comparison of Alfalfa and Sericea Hay. North Carolina Agricultural Experiment Station Annual Report 58: 55.

(3) Helm, C. A., and W. C. Etheridge. December, 1933. Lespedeza Sericea. Missouri Agricultural Experiment Station Bulletin 331. Illustrated. 15 pages.

(4) Holdaway, C. W., W. B. Ellet, J. F. Eheart, and A. D. Pratt. 1936. Korean lespedeza and lespedeza sericea hays for producing milk. Virginia Agricultural Experiment Station Bulletin 305. 7 pages.

(5) Mooers, C. A., and H. P. Ogden. 1935. Lespedeza sericea. Tennessee Agricultural Experiment Station Bulletin 154. Illustrated. 19 pages.

LIMITED VS. FULL-FEEDING IN RECORD OF PERFORMANCE TESTS FOR BEEF CATTLE

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THE method of feeding for record of performance tests in beef cattle as well as other meat animals has been discussed for several years. This discussion has arisen mainly from a lack of agreement on objectives in performance of meat animals. Two measures of efficiency are recognized by animal husbandmen, namely: gross efficiency and net efficiency. Gross efficiency of gains is defined as total gain per unit of total feed. Net efficiency of gains is the total gain per unit of feed in excess of maintenance. To measure gross efficiency will require but little calculation and somewhat simpler experimental technics. Net efficiency has proven much more difficult to measure and as yet there is little evidence on the inheritance of differences in it. The writers have taken the viewpoint that the beef producer desires an animal that when placed in the feed lot with an unlimited supply of feed will make rapid gains and efficient use of its feed and produce a marketable finished animal.

It is the purpose of this paper to present some results on the differences between limited- and full-fed steers in record of performance research in beef cattle. These data came from experiments not designed expressly to determine this point, but from a large project for testing performance in beef cattle.

Review of Literature

Lush (1938) suggested that all animals should be kept under an environment like that for which their offspring are being bred. That is, if animals are being bred for resistance to certain unfavorable conditions, the animals should be kept under these unfavorable conditions so that the breeder will have an opportunity to select the animals that respond best to this unfavorable environment. He suggests that feeding under forced conditions may lead to selection of genes that would not respond favorably to a less favorable environment.

Hammond (1940) stated that selection for certain characters should be made under conditions which are such as to display properly the character in question. For example, he finds that as animals grow they change shape or conformation. This is brought about by the different growth rates of various tissues and parts of the animal. He states further, "The early devel-

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oping parts and tissues of the body have priority of nutrition over the later growing parts and tissues so that when the level of nutrition is low it is the later developing parts (such as loin and fat) which suffer most. Thus it is not possible to make proper selection of animals for a high proportion of loin or fat under conditions where food supply is limited, for the development of these parts and tissues will be limited, not by the genetic capabilities of the animal but by the environmental food supply." He concludes that when we wish to direct the improvement of an animal in any respect it should be placed "in an environment which allows full expression of the character in question."

Rice (1942) suggested that to select breeding animals for an upper rate of production the environment should be at such a level that the upper rate of production may be at least approximated.

Knapp *et al.* (1941) have shown that all steers would gain at approximately the same rate if they were fed limited supplies of grain in order to force them to eat a greater quantity of hay.

Black and Knapp (1936) suggested that beef cattle be self-fed for performance testing since animals that will consume large amounts of feed in excess of maintenance requirements are desired.

Phillips *et al* (1942) have shown that cross-bred steers under limited feeding did not outgain pure-bred steers nearly as much when both were limited fed as when they were full fed. Not all steers had an opportunity to express their full growth potentialities under limited feeding. Their results show a difference of approximately 25 pounds between cross-bred and pure-bred in gains in the feedlot, whereas under unlimited feeding the difference was approximately 70 pounds.

Material and Methods

The two feeding years of 1939–40 and 1941–42 at the U. S. Range Livestock Experiment Station, Miles City, Montana were selected because they differed mainly in the level of feeding though there was also some difference in the concentrate mixture. In 1939–40, the steers were fed a limited grain ration so that they would consume 3 to 5 pounds of hay per day per animal. They were fed a mixture of half corn and half beet pulp in addition to the alfalfa hay. In 1941–42 the steers were fed a grain ration of 6 parts of corn, 3 parts of beet pulp, 1 part of wheat bran, 1 part of linseed meal, plus alfalfa hay. The grain and hay were both fed unlimited and the steers consumed much larger quantities of grain than during the 1939–40 feeding year. Analyses of variance as described by Snedecor (1937) were used to test differences between sire groups.

Data

The frequency distribution of feed consumption per day in total digestible nutrients and of daily gain for the individual steers under limited and ad libitum feeding are shown in figure 1. The total digestible nutrients under limited feeding varied from 8 pounds to 10½ pounds per head. Under ad libitum feeding, the average consumption approximated 10 pounds per day and the highest consumption was from 12½ to 13 pounds per day. Under limited feeding there was much less variation in nutrients consumed than under ad

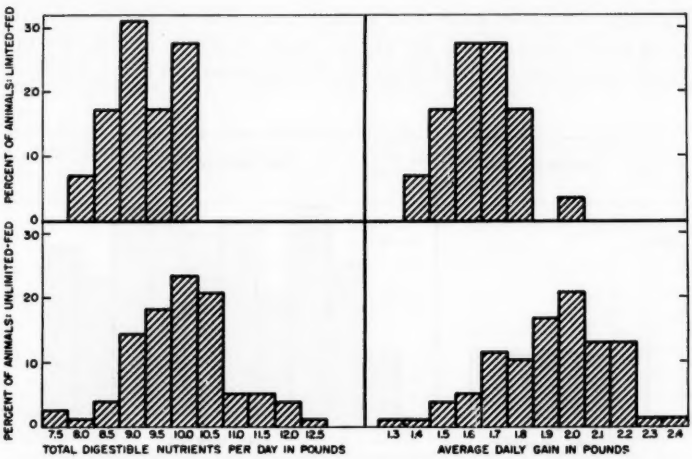
PERCENT OF ANIMALS: LIMITED-FED
PERCENT OF ANIMALS: UNLIMITED-FED
0
10
20
30
7.5 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0 12.5
TOTAL DIGESTIBLE NUTRIENTS PER DAY IN POUNDS
1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0 2.1 2.2 2.3 2.4
AVERAGE DAILY GAIN IN POUNDS

Figure 1. Frequency distributions showing variation in total digestible nutrients per day and in average daily gain for limited and full fed groups of steers.

libitum feeding. There was approximately a normal distribution of nutrient consumption with ad libitum feeding. Under limited feeding, the highest consumption of digestible nutrients was approximately the average consumption under ad libitum feeding. In other words, the steers were fed up to the average consumption of what they probably would have consumed had they been under ad libitum feeding and the heavy consuming steers had no chance to consume the extra quantities they desired. Over 35 per cent of the steers on unlimited feeding consumed in excess of the maximum consumption on limited feeding.

The daily gains show almost the same results (Figure 1). The average daily gain when limited fed was 1.68 pounds whereas under unlimited feeding it

was 1.97 pounds per day. The majority of the limited fed steers averaged 1.6 and 1.7 pounds per day. Under ad libitum feeding there was a more nearly normal frequency distribution and the steers varied from 1.3 pounds per day to 2.4 pounds per day. In other words, under limited feeding there was a tendency for all the steers to gain at approximately the same rate whereas under unlimited feeding there was considerably more variation in daily gains.

When the various sire groups were compared it was found that those under limited feeding all gained at approximately the same rate (Figure 2). The range in variation is only 0.01 pound per day. This is based on the average of 6 to 8 steers in each sire group. Under ad libitum feeding, the sire groups varied from 1.69 pounds per day to 2.10 pounds per day, a difference

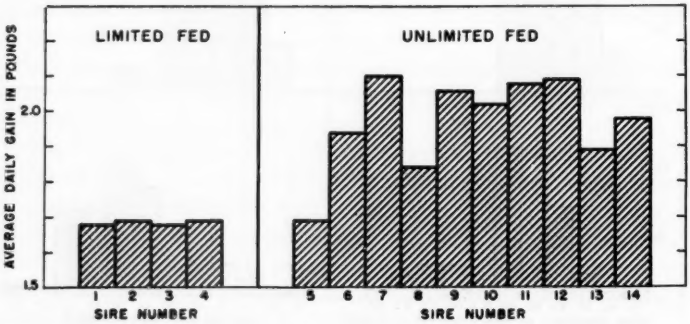

Figure 2. Differences between sire groups in average daily gains. Each sire average is based on 6 to 8 steers in each group.

of 0.41 pound. In other words, under limited feeding the sire groups gained almost exactly the same as the average for all groups whereas under unlimited feeding there is a large variation in the rates of gain among the different sire groups. Analyses of variance bring out this point quite strongly (Table 1). Under limited feeding the sire groups were significantly more alike in daily gains than would be expected by chance ($P < .05$). The variance within sire groups was significantly larger than the variance observed between sire groups. This may be interpreted to mean that some controlling factor made these groups more alike than the chance variation within sire groups would indicate. In the unlimited fed steers, the sire groups were significantly more different than would be expected by chance ($P < .01$) or in other words the variance between sire groups significantly exceeded the

variance within sires. This was not due to less variation within sire groups under unlimited feeding (actually this difference was in the other direction), but rather that there was more variation between sire groups.

Discussion

The objective of performance testing and the final goal in breeding beef cattle are of primary consideration before it can be determined whether limited or unlimited feeding should be practiced. It is believed that the beef producer desires an animal that will readily convert feed into rapid gains and produce a final product of marketable value. Under certain conditions, however, this might be modified, as for example, under range conditions the range cattleman is desirous of having an animal that can take a limited feed supply and remain in a healthy condition. However, the rangeman is also desirous of

TABLE 1.—ANALYSES OF VARIANCE OF DAILY GAINS AND TOTAL DIGESTIBLE NUTRIENTS PER DAY FOR LIMITED AND UNLIMITED FED STEERS

Item	Source of variance	Limited fed steers	Unlimited fed steers
Degrees of freedom	Between sire groups	3	9
	Within sire groups	25	67
Mean squares of daily gain	Between sire groups	0.0012*[1]	0.1243**
	Within sire groups	0.0166	0.0408
Mean squares of daily consumption of T.D.N.	Between sire groups	0.5916	1.7387*
	Within sire groups	0.3719	0.8037

[1] Significantly more alike than would be expected by chance.
* $P<.05$.
** $P<.01$.

producing the type of animal that when placed in the feed lot with unlimited feed supply will make rapid gains and efficient use of its feed. In general, then, the usual conditions of beef production for the market are unlimited feeding. It would seem that the usual environmental conditions under which beef cattle are being bred, as suggested by Lush (1938), are in this case forced feeding conditions. The real purpose of performance in beef cattle should be, therefore, to develop an animal that will gain rapidly under forced conditions. Since degree of fatness largely determines the marketability of our finished animals, the suggestion by Hammond (1940) seems entirely in line with the proposals of unlimited feeding.

The data show that genetic variation in ability to use unlimited quantities

of feed (growth) was masked when all animals were fed somewhat alike. If variation in growth (use of unlimited feed supply) is to be our objective, then certainly the only possible way to measure this variation is by some method that will bring out the growth variations between animals by the same sire and between animals from different sires. The animals under unlimited feeding consumed varying amounts of feed and some sire groups consumed significantly more feed than other groups. These data indicate that limited feeding as applied in these tests measured neither ability to gain on set quantities of feed nor ability to gain on unlimited quantities of feed.

It was shown above that under unlimited feeding there were greater variations among calves by the same sire as well as greater differences between calves by different sires than was observed in such classes under limited feeding. The differences between groups by the various sires were significantly larger than the variance within sires even though the latter were larger under unlimited feeding. Variations between sires are not likely to exist unless there are considerable variations between animals by the same sire. It should not be expected that all calves by the same sire will grow exactly alike since they receive half of their inheritance from their dams and the sires themselves are not entirely homozyzous and of course not all the variation is hereditary anyhow. There is little possibility to do any selection for superior performance in a homogeneous population whether this homogeneity be due to the hereditary influences of the genes governing growth or to environmental influences. It would seem logical to conclude from the above study that if growth differentiation is one of the objectives of performance testing in beef cattle, then forced feeding or ad libitum feeding is the best method by which that may be determined.

Summary

The results from limited and unlimited feeding in two different years for testing performance at the U. S. Range Livestock Experiment Station, Miles City, Montana, are studied. The steers were fed slightly different rations.

Frequency distributions of the total digestible nutrients consumed and daily gains of the steers show that on limited feeding the steers were much less variable in daily gains than on unlimited feeding. Variance analyses showed that on limited feeding the sire groups were significantly more alike than would be expected by chance whereas on unlimited feeding the sire groups were significantly different from each other.

It was concluded that forced or ad libitum feeding is the best method by which differences in ability to grow may be determined.

Literature Cited

Black, W. H., and Bradford Knapp, Jr. 1936. A Method of Measuring Performance in Beef Cattle. Proc. Am. Soc. An. Prod. 1936: 72–77.

Hammond, John. 1940. Farm animals, Their Breeding, Growth, and Inheritance. 199 pp., illus. New York.

Knapp, Bradford, Jr., A. L. Baker, J. R. Quesenberry, and R. T. Clark. 1941. Record of Performance in Hereford Cattle. Mont. Agr. Expt. Sta. Bull. 397. 30 pp.

Lush, Jay L. 1938. Animal Breeding Plans. 350 pp. illus. Ames.

Phillips. Ralph W., W. H. Black, Bradford Knapp, Jr., and R. T. Clark. 1942. Crossbreeding for Beef Production. JOURNAL OF ANIMAL SCIENCE 1: 213–220.

Rice, Victor Arthur. 1942. Breeding and Improvement of Farm Animals, 3rd edition. 750 pp. illus. New York.

Snedecor, George W. 1937. Statistical Methods. 341 pp. illus. Ames.

THE UTILIZATION OF UREA AND SOYBEAN OIL MEAL NITROGEN BY STEERS[1]

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RECENT experiments have proven that urea can make up a considerable portion of the protein requirements of ruminants. The nitrogen balance experiments of Fingerling *et al.* (1937) on two growing calves; the nitrogen balance studies, growth and slaughter experiments of Harris and Mitchell (41a and 41b) on sheep; and the nitrogen balance experiments of Johnson *et al.* (1942) on sheep are clear cut; while the growth experiments on calves of Bartlett and Cotton (1938); Work and Henke (1939), and Hart *et al.* (1939) furnish convincing evidence that low protein rations, inadequate for growth in calves, and inadequate for maintenance and growth in sheep, are efficiently supplemented by urea. Wegner *et al.* (1940) showed "In Vitro" conversion of inorganic nitrogen to protein by using microorganisms from the cow's rumen. A more recent experiment by Mills *et al.* (1942) has shown conversion of urea to ammonia with the subsequent conversion to protein in the rumen. Lenkeit and Becker (1938) also showed that urea is transformed into ammonia in the sheep's rumen.

The experiments reported here were undertaken with the conviction that urea can be utilized by ruminants. The purpose of the experiments was: first, to measure the efficiency of conversion of urea to protein by determining the biological value of urea in comparison with that of soybean oil meal; second, to extend the biological method of evaluating proteins to cattle; and third, to shed further light on the conversion of urea to true protein in the rumen of steers.

Plan of the Experiments

The first experiment consisted of nitrogen balance studies on four Holstein steers ranging in age from 6 to 8 months and ranging in weight from 140 to 211 kgm. in body weight. The collection periods were 6 to 10 days in length with an adequate preliminary period to adjust the steers to a change of rations by determining daily the amount of nitrogen excreted in the urine. When the urinary nitrogen reached a constant daily output for a period of not less than 6 days the urine and feces were composited and analyzed.

Mitchell's (1924) biological value method as adapted to laboratory ani-

[1] Technical paper 112 of The Hawaii Agricultural Experiment Station.
[2] Formerly Junior Animal Husbandman.
[3] Formerly Associate Animal Husbandman.
[4] Animal Husbandman.

mals was used to calculate the quantitative utilization of the nitrogen of urea and soybean oil meal. The information was secured from three feeding periods. Period 1 consisted of feeding a low nitrogen ration; period 2, the same ration with substituted amounts of urea or soybean oil meal to raise the protein equivalent up to 12 to 14%; and period 3, a repetition of period 1. The average values for periods 1 and 3 gave the endogenous nitrogen, which is the loss of nitrogen from the body in the urine, and the metabolic nitrogen, which is the loss of nitrogen from the body in the feces.

The composition of the low nitrogen ration (No. 1), the urea ration (No. 2), and the soybean oil meal ration (No. 3) is given in table 1.

TABLE 1.—COMPOSITION OF RATIONS

	Ration No.				
	1[1]	2[1]	3[1]	4[2]	5[2]
	per cent	*per cent*	*per cent*	*per cent*	*per cent*
Pineapple syrup	45.0	45.0	45.0	40.0	40.0
Pineapple bran	—	—	—	45.0	39.0
Raw sugar	14.0	14.0	4.9	13.0	13.0
Cottonseed oil	4.0	4.0	4.0	—	—
Sifted bagasse	15.0	15.0	15.0	—	—
Dried cassava meal	20.0	14.88	—	—	—
Salt (NaCl)	1.0	1.0	1.0	1.0	1.0
Steamed bone meal	1.0	1.0	1.0	1.0	1.0
Urea (Uramon)	—	5.12	—	—	6.0
Soybean oil meal	—	—	29.1	—	—
Total	100.0	100.0	100.0	100.0	100.0
Protein	1.44	12.38	13.81	2.61	17.25
Dry matter	80.80	77.20	75.80	—	—

[1] In addition each steer received 10 cc. of cod liver oil concentrate per day (Nopco xx).
[2] In addition each steer received 20 pounds of Napier grass per day.

The second experiment was conducted on two groups of four mature steers. One group received ration 4 which was low in nitrogen and the other received ration 5, which contained 6 per cent urea (table 1).

The steers were each fed 10.5 pounds of the concentrate mixture and 20 pounds of Napier grass, divided into two feeds, for 10 days. On the morning of the eleventh day, the steers were fed the concentrate mixture without the Napier grass and were slaughtered five hours later.

At the time of slaughter a sample of the rumen contents, and a weight of the total contents was taken. The samples were analyzed for total nitrogen, urea and ammonia. It was assumed that true protein nitrogen was obtained by subtracting the urea and ammonia nitrogen from the total nitrogen.

Urea was determined by the urease method and ammonia by magnesium oxide distillation. Total nitrogen was determined by the Kjeldahl method.

Since the feeds used in these experiments are not widely known, their composition is given in table 2.

TABLE 2.—COMPOSITION OF FEEDS USED

Feed	Dry matter	Nitrogen	Ether extract	Fiber	Ash	Nitrogen-free extract
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Sifted bagasse	90.19	0.320	1.16	41.15	2.69	43.19
Dried cassava meal	85.60	0.168	0.72	3.16	2.03	78.64
Pineapple syrup	76.30	0.336	1.60	0.00	3.40	70.96
Pineapple bran	90.36	0.682	0.88	15.42	3.14	70.24
Soybean oil meal	90.73	7.15	5.27	5.49	5.44	29.85
Urea (Uramon)[1]	99.38	40.66	—	—	—	—

[1] Uramon is the trade name for urea which is usually used as a fertilizer for sugar cane. It was purchased from E. I. DuPont de Nemours Company.

TABLE 3.—ENDOGENOUS AND METABOLIC NITROGEN PER DAY

Steer No.	Period No.	Endogenous nitrogen		Metabolic nitrogen per 100 gm. dry matter
		Per sq. m. body surface[1]	Per kgm. body wt.	
		gm.	*gm.*	*gm.*
9	1	2.08	0.030	0.426
	3	2.22	0.032	0.442
Average		2.15	0.031	0.434
10	1	2.52	0.040	0.528
	3	1.94	0.031	0.442
Average		2.23	0.036	0.485
11	1	1.99	0.033	0.505
	3	2.02	0.034	0.570
Average		2.00	0.034	0.538
12	1	1.98	0.037	0.603
	3	2.04	0.035	0.397
Average		2.01	0.036	0.500
Average all		2.10	0.034	0.489

[1] Using Brody and Elting's (1926) formula where the body surface in square meters $=0.15\ W\ \text{kgm.}^{0.56}$

Experimental Results and Discussion

Experiment 1

The endogenous and metabolic nitrogen. The endogenous nitrogen (table 3) was almost constant for each period and averaged 0.034 gm. per kilogram of body weight, and 2.10 gm. per square meter of body surface. The endogenous nitrogen measures the minimum protein requirements for maintenance. Using a biological value of 50 as Smuts and Marais (1938) have proposed for sheep, the net amount of digestible protein for maintenance of steers 6 to 8 months of age would be 0.425 gm. per kilogram of body weight.

With the exception of steer 12, the metabolic nitrogen (table 3) was quite constant for both periods. It averaged 0.489 gm. per 100 gm. of dry matter consumed. Technically speaking, the metabolic nitrogen is a part of the protein maintenance requirement too, but since it varies with the dry matter consumed, it is more logically charged to digestion.

The nutritive effects of urea and soybean oil meal. The appetites of the steers always improved on the transition from the low-nitrogen ration to the urea or soybean oil meal rations. The animals also lost slightly in weight while on the low-nitrogen ration, but gained in weight while on the urea or soybean oil meal rations.

The nitrogen balance (table 4) was consistently negative on the low-nitrogen ration and positive on the urea or soybean oil meal ration. Thus it is clear that the nitrogen was utilized.

The digestion coefficients, per cent of nitrogen stored, and biological values are summarized in table 5. Urea furnished 88.4% and soybean oil meal 89.6% of the protein equivalent (N%×6.25) of the rations fed.

The average apparent digestion coefficient of urea nitrogen was 74 and that of soybean oil meal 78, while the true digestibility averaged 94 for both sources of nitrogen.

The average per cent of the nitrogen stored was 2.0% for urea and 31.4% for soybean oil meal.

The average biological values of urea and soybean oil meal nitrogen were 34 and 60 when fed at levels of 12.4 and 13.8% protein equivalent, respectively. At these levels of feeding, soybean oil meal nitrogen is 1.8 times as valuable as urea nitrogen in satisfying the maintenance and growth requirements for nitrogen for calves 6 to 8 months old. The biological value of 60 for soybean oil meal supports the theory presented by Johnson *et al.* (1942) that protein fed at about a 12% level to all ruminants has a biological value of 60.

The poor utilization of urea nitrogen in this experiment probably means that it was fed above the level of conversion into true protein by the rumen

TABLE 4.—DAILY NITROGEN BALANCE

Steer No.	Length of period	Ave. body wt.	Dry matter eaten	Nitrogen intake	Nitrogen output		Nitrogen balance
					In feces	In urine	
	days	*kgm.*	*gm.*	*gm.*	*gm.*	*gm.*	*gm.*
Period 1, Basal ration 1							
9	7	196	2161	6.15	9.20	5.99	−9.04
10	7	170	2031	5.78	10.73	6.70	−11.65
11	6	144	1650	4.70	8.34	4.82	−8.46
12	6	116	1616	4.60	9.75	4.25	−9.40
Average		156	1864	5.31	9.50	5.44	−9.64
Period 2, Urea ration 2							
10	10	167	2470	63.36	14.98	46.42	1.96
11	10	149	2162	55.44	16.23	38.77	0.44
Average		158	2316	59.40	15.60	42.60	1.20
Period 2, Soybean oil meal ration 3							
9	10	209	2729	79.56	18.38	33.70	27.48
12	10	126	1819	53.04	11.77	26.31	14.96
Average		168	2274	66.30	15.08	30.00	21.22
Period 3, Basal ration 1							
9	9	208	2217	6.31	9.77	6.60	−10.06
10	9	168	1667	4.71	7.38	5.13	−7.80
11	9	143	1230	3.58	7.01	4.87	−8.30
12	9	135	1939	5.52	7.69	4.78	−6.95
Average		164	1763	5.03	7.96	5.34	−8.27

microorganisms. Since the urine nitrogen was very high in the urea periods, and there was no appreciable difference in the digestibility of the two sources of nitrogen, it would seem that possibly ammonia was absorbed, converted to urea in the liver, and subsequently excreted by the kidneys, or else the biological value of the protein produced by the microorganisms was very low. The first view seems more logical because urea is converted to ammonia very fast (Lenkeit and Becker 1938 and Mills *et al.* 1942). Hart *et al* (1939) have also shown that diuresis as well as kidney damage takes place when large amounts of urea are fed. Under the above theory, if urea is fed much above the point of maximum conversion to protein, the kidneys would have

TABLE 5.—DIGESTION COEFFICIENTS FOR NITROGEN, PER CENT OF NITROGEN STORED, AND BIOLOGICAL VALUES OF UREA AND SOYBEAN OIL MEAL NITROGEN

Steer No.	Ration[1]	Digestibility of nitrogen		Dietary nitrogen stored	Biological value
		apparent	true		
		per cent	*per cent*	*per cent*	*per cent*
10	Ration 2 (urea)	76	95	3.1	33
11	Ration 2 (urea)	71	92	0.8	34
	Average	74	94	2.0	34
9	Ration 3 (soybean oil meal)	77	92	34.5	63
12	Ration 3 (soybean oil meal)	78	95	28.2	57
	Average	78	94	31.4	60

[1] Urea furnishing 88.4 per cent of the protein equivalent and soybean oil meal 89.6 per cent of the protein equivalent of the rations fed.

TABLE 6.—WEIGHTS AND CHEMICAL COMPOSITION OF RUMEN CONTENTS FIVE HOURS AFTER SLAUGHTER

Steer No.[1]	Wet weight of contents	Dry matter	Total nitrogen	Ammonia nitrogen	Urea nitrogen	True protein nitrogen	
						Fresh	Dry matter
	kgm.	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Group 1 ration 4 no urea							
He-4	52	13.37	0.168	0.0026	0.0	0.165	1.24
He-6	29	12.33	0.270	0.0079	0.0033	0.259	2.10
H-1	67	15.82	0.255	0.0031	0.0002	0.252	1.59
H-2	62	14.80	0.183	0.0022	0.0	0.181	1.22
Average	52	14.08	0.219	0.0040	0.0009	0.214	1.54
Group 2 ration 5 urea							
He-3	79	12.36	0.362	0.0138	0.0	0.348	2.82
He-5	78	12.20	0.338	0.0110	0.0	0.327	2.68
H-7	27	9.71	0.231	0.0181	0.0015	0.211	2.18
H-8	45	13.07	0.319	0.0104	0.0	0.309	2.36
Average	57	11.84	0.312	0.0133	0.0004	0.299	2.51

[1] He stands for Hereford and H stands for Holstein.

to excrete the excess ammonia not used by the microorganisms, resulting in wastage and possible kidney damage. It seems as though the next step would be to find out at what point the highest conversion of urea nitrogen to true protein takes place, to see if ammonia is increased in the blood, and to determine the biological value of the protein produced by the microorganisms.

Experiment 2

The results of the slaughtered steers fed rations 4 and 5 are summarized in table 6. The results show there was very little urea nitrogen present five hours after feeding. In fact, in the animals fed urea there was only one that showed slight amounts. The significant thing is that in all cases the true protein nitrogen was higher in the steers fed urea than in those not fed urea. This is evidence that urea was transformed into true protein in the rumen. All these results agree with those of Mills *et al.* (1942).

Since the rumen is in constant motion, with material entering and leaving, it is difficult to figure out how much protein is synthesized per day. However, at the time of sampling there was 6.06% more protein (dry basis) contained in the paunch material of the steers fed urea than in those not fed urea. Hence, as material passed out of the rumen it would cont. in 6.06% more protein in the steers fed urea than in those not fed urea if measured five hours after feeding.

Summary and Conclusions

Nitrogen balance experiments were conducted on four steers. In addition, one group of four steers was fed a ration of low-nitrogen content and a second group a similar ration with a substitution of 6.0% urea. These steers were slaughtered and the rumen contents were analyzed for total nitrogen, urea and ammonia.

Under the conditions of these experiments the conclusions are:

1. The endogenous nitrogen of 6 to 8 month old steers averages 0.034 gm. per kgm. of body weight or 2.10 gm. per square meter of body surface. The metabolic nitrogen in the feces averages 0.489 gm. per 100 gm. of dry matter consumed.

2. The apparent digestion coefficient of urea nitrogen when fed to 6 to 8 month old steers is 74 and that of soybean oil meal 78. When corrected, for the metabolic nitrogen in the feces, the values are 94 for each source of nitrogen.

3. The biological value of urea nitrogen when fed to 6 to 8 month old steers is 34 and that of soybean oil meal nitrogen 60 when fed at 12 and 14% protein equivalent levels. The poor utilization of the urea nitrogen probably means that it was fed above the maximum conversion to true protein by the microorganisms of the rumen.

4. More true protein is found in the rumen of steers receiving urea than those subsisting on the same low protein ration without urea. This fact supports the theory that protein is manufactured in the paunch of ruminants.

Literature Cited

Bartlett, S., and A. G. Cotton. 1938. Urea as a Protein Substitute in the Diet of Young Cattle. J. Dairy Res., 9: 263–272.

Brody, S., and E. C. Elting. 1926. Growth and Development with Special Reference to Domestic animals. II. A New Method for Measuring Surface Area and its Utilization to Determine the Relation Between Growth in Surface Area and Growth in Weight and Skeletal Growth in Dairy Cattle. Mo. Agr. Exp. Sta. Res. Bull., 89, 18 p.

Fingerling, G., B. Hientzsch, H. Kunze, and K. Reifgerst. 1937. Ersatz des Nahrungeiweisses durch Harnstoff beim waschsenden. Rinde. Landw. Vers. -Stat., 128: 221–235.

Hart, E. B., G. Bohstedt, H. J. Deobald, and M. I. Wegner. 1939. The Utilization of Simple Nitrogenous Compounds Such as Urea and Ammonium Bicarbonate by Growing Calves. J. Dairy Sci., 22: 785–798.

Harris, L. E., and H. H. Mitchell. 1941a. The Value of Urea in the Synthesis of Protein in the Paunch of the Ruminant. I. In Maintenance. J. Nutrition, 22: 167–182.

Harris, L. E., and H. H. Mitchell. 1941b. The Value of Urea in the Synthesis of Protein in the Paunch of the Ruminant. II. In Growth. J. Nutrition 22: 183–196.

Johnson, B. C., T. S. Hamilton, H. H. Mitchell, and W. B. Robinson. 1942. The Relative Efficiency of Urea as a Protein Substitute in the Ration of Ruminants. JOURNAL OF ANIMAL SCIENCE, 1: 236–245.

Lenkeit, W., and M. Becker. 1938. Das Schicksal des Harnstoffs der Amidflocken im Pansen. Zeit. Tierernähr. in Futtermittelkunde, 1: 97–101.

Mills, R. C., A. N. Booth, G. Bohstedt, and E. B. Hart. 1942. The Utilization of Urea by Ruminants as Influenced by the Presence of Starch in the Ration. J. Dairy Sci., 25: 925–929.

Mitchell, H. H. 1924. A Method of Determining the Biological Value of Protein. J. Biol. Chem., 58: 873–903

Smuts, D. B., and J. S. C. Marais. 1938. The Endogenous Nitrogen Metabolism of Sheep with Special Reference to the Maintenance Requirement of Protein. Onderstepoort J. Vet. Sci. and An. Indust., 11: 131–139.

Wegner, M. I., A. N. Booth, G. Bohstedt, and E. B. Hart. 1940. The "In Vitro" Conversion of Inorganic Nitrogen to Protein by Microorganisms from the Cow's Rumen. J. Dairy Sci., 23: 1123–1129.

Work, S. H., L. A. Henke. 1939. The Value of Urea as a Protein Supplement Replacement for Dairy Heifers. Proc. Am. Soc. An. Prod., pp. 404–406.

SOME FACTORS ENCOUNTERED IN EXPERIMENTS TO EVALUATE FEEDS FOR FATTENING LAMBS

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Introduction

THOUSANDS of feed lot comparisons have been made in the United States to compare the values of various feeds for productive purposes. Valuable data have been accumulated through these trials, and much information has been secured concerning the relative feeding values of many important feeds. However, it has been difficult to arrive at the actual comparative value of feeds when experimental lots of animals have made different rates of gain or produced varying quantities and qualities of product. Interest has been aroused in methods of determining the net energy or productive energy of feeds by carefully conducted feed-lot investigations in which gains are controlled between the lots by varying the intake of the feeds studied. Such a procedure should have the advantage of uniform gains and that all feeds except the ones being investigated would be consumed in identical amounts.

It is the purpose of this paper to present the results and experiences of six years' investigation in which the controlled gain method has been used in comparing the values of common feeds for fattening lambs.

Review of Previous Investigations

Kellner (1905) was the first investigator to publish extensive tables of net energy values of the various feeding stuffs. The Danish feed unit system, described by Morrison (1936), was developed as an outgrowth of a desire to express the value of one feed in terms of a standard feed such as corn or barley. This method of comparing feeds actually compares their economic feeding values when added to common rations rather than measuring their actual net energy values.

Armsby and Fries (1903) measured calorimetrically the value of feeds when fed to large animals. Later they (1915) published a method of computing the energy value of a feed from its chemical composition. Armsby (1917) published a table of the energy values of a considerable list of American feeding stuffs. Eight years later, Forbes and Kriss (1925) published some revised net energy values for cattle.

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Forbes and associates (1928) published evidence that the net energy value of a feed for steers was dependent on the level of feeding, and that the highest net energy value of a unit of feed was secured when it was fed at or below maintenance levels. This report was followed by further studies (1930) in which it was shown that the seven levels of feeding, ranging from fast to three times maintenance, resulted in a heat loss from steers that was described by an S-shaped curve. Confirmatory results were secured with rats (1934). Mitchell and co-workers (1932) found the heat loss from a steer fed at six levels of feeding from fast to full feed increased in a linear manner. Brody and Proctor (1933) have also shown that the level of energy intake has a marked effect on the heat increment of the ration.

Various workers have shown that a deficiency of some dietary essential may decidedly alter the net energy value of a feed. Swift, *et al.* (1934) showed that a lack of cystine in the diet decreased the net energy value of a feed. Similarly McClure, Voris, and Forbes (1934) found that the net energy value of feed is lowered when there is a lack of vitamin B in the rat diet. More recently Kahlenberg, Black, and Forbes (1937) have reported a sodium deficiency results in depressed utilization of nutrients. Kleiber, Goss, and Guilbert (1936) secured data which suggest that a phosphorus deficiency lowers energy utilization for beef heifers through a decreased appetite.

Forbes, *et al.* (1933) point out that the net energy value of a feed is very much dependent on the combination of feeds in which it is fed.

Mitchell and Hamilton (1941) have concluded that the extent to which metabolizable energy is utilized for maintenance and tissue synthesis in growing calves is not the function of the particular feeds included in the ration, but is dependent, immediately or eventually, on the adequacy of the combination of digestible nutrients presented to the tissues.

Forbes and associates (1935) secured evidence that inadequate levels of protein lowered the net energy value of a ration. The rate of growth and energy storage was increased with the higher protein levels. Hamilton (1937) has confirmed these findings and found that protein levels above 30 per cent increased heat loss.

Johnson, Hogan, and Ashworth (1936) fed growing, paired rats different levels of protein. It was observed that growth, as measured by gain in weight was more rapid on the diet reasonably high in protein, due to the kind of nutrients stored but that energy storage was similar.

Forbes, *et al.* (1938) extended their work by using higher levels of protein. When the protein level was increased above 24 per cent, both body gain and fat storage were reduced. The net energy value of the ration declined progressively from the 25 per cent to the 45 per cent protein level.

Mitchell, Hamilton, and Haines (1940) found that the utilization of the

metabolizable energy in the ration of the calf was not impaired by inadequate levels of protein within limits of 6 per cent and 20 per cent tested.

Kriss (1938) has reported a study in which different amounts of protein supplement were added to a basal ration of nearly mature albino rats. No significant difference was observed in either the specific dynamic action or the net energy values of the protein supplements at the different levels.

Braman, *et al.*, (1935) report similarity in energy storage from rations that failed to produce the same liveweight gain. Rats consuming yellow corn gained more rapidly and appeared in better health than those receiving white corn, but carcass analysis showed they had made no greater caloric storage. These same workers found that high levels of vitamin A increased gains over a deficient amount of the vitamin when fed to rats, but that the increase was caused by water and protein. Rations lacking in vitamins D and G resulted in unhealthy animals that failed to store energy as rapidly as normal rats.

Forbes (1933) has stated the necessity of making net energy determinations on satisfactory rations in his Law of Maximum Normal Nutritive Value.

Other factors naturally affect the utilization of energy in a ration. Ritzman and Benedict (1930) (1931) have shown that the metabolism level of sheep is dependent upon their age, sex, castration, growth, oestrus, and lactation. It appears from the data of Ritzman and Benedict (1930) (1931) that wether lambs of the age ordinarily used as feeders are desirable subjects for energy studies. Sheep have been found by Watson *et al.* (1937) to respond very readily to changes in energy intake.

Some workers have felt that data expressing the actual productive or net energy value of feeds would be more reliable in expressing the true comparative value or energy content of common feeds than values commonly used. Fraps (1931) computed production values, from the results secured in lamb fattening experiments at the Texas Station, in which various rations were directly compared. With these production values, he computed energy values of feeds from the data secured in lamb fattening experiments by other investigators.

Net energy values of feeds have been criticized as practical measures of feeding value. These criticisms are, no doubt, partially based on the fact that Armsby (1917) found timothy hay to have a net energy value of 32 therms as compared to the value of 34 therms which he found for alfalfa hay. Mitchell, Kammlade, and Hamilton (1928) secured similar data in working with sheep. Zuntz and Hagemann (1898) had found that alfalfa hay had a higher net energy value for horses than did timothy hay. Ritzman and Benedict (1931) confirmed their results with dairy cattle.

Morrison and Salisbury (1934) fed good quality alfalfa and timothy hays in well-balanced rations to high producing dairy cows. Equal amounts of the two hays were fed, and the same amount of fat-equated milk was produced by both rations. The two groups of cows made similar changes in body weight. The varying results secured on these hays by various students of energy make it clear that the net energy values of these roughages are greatly dependent upon how they are fed and the method of measurement.

The quality of a feed may influence its net energy content. Ritzman and Benedict (1934) have shown that the net energy of timothy hay is much higher in early cut hay than mature hay.

Morrison (1936) has published a table of estimated net energy values of American feeding stuffs. In making his estimates, Morrison drew upon the values of Kellner, Armsby, Forbes, and Fraps, as well as upon the many direct feed-lot comparisons that have been made comparing the relative value of various feeds.

A symposium was conducted at the American Society of Animal Production meetings in 1937 on methods of comparing the values of feeds. Fraps (1937) discussed his method of estimating the productive energy values of feeds and Morrison (1937) suggested feed lot trials as a method of determining net energy values. Forbes (1937), Mitchell (1937), Guilbert and Hart (1937), and Hart (1937) discussed these proposals and pointed out the inherent shortcomings.

Morrison's (1937) plan suggested carefully controlled feed lot experiments be used to secure data on the relative net energy value of feeds for productive purposes. Two uniform lots of animals were to gain at the same rate with both lots of animals receiving well-balanced rations which were alike except for the feeds whose productive values were being specifically studied. He stressed that considerations must be given to adequate supplies of vitamins and proteins in the test rations. The difference in the amount of two feeds required to produce the same results would then express the comparative values of the one feed in terms of the other. The net energy value of the unknown feed could be easily calculated from the feed used as a standard. He further proposed that the feed lot data be checked with slaughter and carcass data on the experimental animals to see if equal performance had actually been secured. This plan of attack has been used in this study.

Experimental Objectives

Two separate series of feed lot experiments were designed to find the relative feeding value of common lamb fattening feeds. The first series was designed to compare (1) the relative value of cottonseed meal, 43 per cent protein grade, with that of shelled yellow dent corn, and (2) the relative value of prairie hay with that of alfalfa hay.

The second series of experiments was conducted to compare the relative value of oats and barley with that of shelled yellow corn when each were fed alone, and in combination with corn. Information was also sought as to the value of barley when fed with corn and with oats.

Method of Procedure

During the six years covered by this study, 120 head of Texas feeder lambs, with Rambouillet breeding predominating were fed each year. The lambs were secured in early October, ear tagged, stenciled, and drenched with copper sulphate and nicotine sulphate solution. In three to four weeks after arrival the lambs were on approximately a full feed of the feeds to be studied.

An average of three daily weights was taken as the initial weight and similar weights were made at the close of the experiment. In the first series of experiments the lambs were weighed every 7 days, but in the second series weights were taken every 14 days.

The lambs had adequate shelter to protect them from the elements and give them a dry place to lie. They were kept constantly in a dry lot the outside portion of which was paved with brick. Clean water, salt, and a simple mineral mixture of equal parts of steamed bone meal, finely ground limestone, and salt were available at all times. No bedding was used except in wet weather when it was necessary to keep the shed dry.

The lambs were hauled to Oklahoma City by truck each of the six years and allowed to remain overnight except the first year when they were hauled the morning sold. The lambs were offered a filling feed of alfalfa hay and allowed all the water they would drink. The lots of lambs were ranked in order of their market quality each year by commission men and packer buyers. These comparative ranks varied widely, as would be expected on lambs with similar gain, and can be regarded as of little value in estimating the values of the feeds studied. After slaughter, the packing company's warm carcass grade was secured for each lamb. Each carcass was given a score corresponding to the grade. The scores assigned were: prime 5, choice 4, good 3, medium 2, and common 1. The carcass weights were taken and the dressing percentage for each lot calculated.

At the start of the feeding period hay was fed in greater amounts than concentrates. The ratio was gradually changed until in the later stages of the experiment the lambs received more concentrates than hay.

Rations Fed. It was intended that Lots I, II, and III, used to study the productive values of yellow corn and 43 per cent cottonseed meal, should all gain at the same rate. Furthermore, the three lots of lambs were fed identical amounts of hay. Any differences in the amount of concentrate required

to produce the same gain should, therefore, be the comparative value of the feeds for fattening lambs. This assumption would be correct only in case all necessary nutrients were supplied above the minimum level required by the animal.

Lot I was used as the check lot. The lambs in this lot were maintained at a level of feeding just slightly under that of full-feeding. It is necessary that each lot of lambs consume the same amount of feed each day between weigh periods, and a slight margin of safety is necessary to take care of the effect that changes in temperature might have upon the appetites.

The amount of corn fed to lot III was one-half that consumed by lot II, and the amount of cottonseed meal fed was dependent upon the amount required to keep the log gaining at the same rate as lot 1.

Lot II was fed no protein supplement in a study of the value of adding small amounts of cottonseed meal to a ration of corn and alfalfa hay for fattening lambs. Morrison (1936) has concluded after summarizing 49 lamb-feeding experiments that small additions of linseed meal or cottonseed meal to a lamb-fattening ration of corn and alfalfa hay will usually slightly increase the rate of gain. He has pointed out, however, that at the usual prices of these supplements their addition to the ration is not economical.

In a similar but separate experiment, lots IV, V, and VI were used to study the relative values of alfalfa and prairie hay. The three lots were all fed the same amounts of concentrates, but the kind and amount of roughage was varied.

Lot IV was used as the check lot and the lambs were fed all the prairie hay they would clean up. The amounts of hay fed to lots V and VI were dependent upon the amounts of hay necessary to keep the respective lots gaining at the same rate as lot V. Ample protein was furnished in lots IV and VI by the liberal allowance of cottonseed meal that was provided in the ration. Finely-ground limestone was added at each feeding to the concentrate mixture in these two lots to overcome the shortage of calcium in the prairie hay. The small amount of alfalfa hay added to the ration of lot VI was included to see if it might supply vitamins and essential minerals that might be lacking in the prairie hay ration.

The feeds used during 1936–37 were produced during the drought year of 1936. Their chemical composition was therefore altered in some cases from normal composition. The prairie hay that was secured for the feeding experiment in 1938–39 was not palatable. Sufficient prairie hay remained from the preceding year and was used instead. Aside from possible deterioration in the hay from one year to the other, this afforded a check of the repeatability of the results of the previous year. Chemical analysis and grades of the feeds used in the first series of experiments are presented in Table 1. The calcu-

lated digestible protein and T.D.N. content of the feeds are also given.

The experimental rations used in the second series of experiments are given in table 6. Lambs in all three lots were fed the same amounts of alfalfa hay and cottonseed meal. Any difference in gain, finish, or carcass grade should therefore reflect the comparative feeding value of the grain. The small

TABLE I.—THE CHEMICAL COMPOSITION[1] AND MARKET GRADES OF FEEDS

Year	Feed	Water	Protein	Fat	Fiber	Ash	N.F.E.	Dig. Protein[2]	T.D.N.[2]	U. S. Market Grade
1936–37	Alfalfa hay	11.73	12.53	1.22	31.98	6.03	36.49	9.0	49.6	2
	Prairie hay	13.42	4.28	1.61	26.60	7.65	46.44	2.0	46.7	3
	Corn	12.73	9.97	3.56	2.30	1.49	69.95	7.6	82.0	5
	Cottonseed Meal	10.18	41.28	5.13	8.66	6.00	28.75	33.5	69.6	—
1937–38	Alfalfa hay	11.72	14.38	.77	28.09	8.34	36.70	10.4	49.3	1
	Prairie hay	9.19	5.63	2.13	30.50	8.87	43.68	2.6	48.5	2
	Corn	12.79	10.11	3.89	1.98	1.41	69.82	7.7	82.3	2
	Cottonseed Meal	7.73	42.88	4.89	11.09	5.19	28.22	34.7	71.4	—
1938–39	Alfalfa hay	10.93	18.36	2.00	27.34	9.88	31.49	13.2	48.8	3
	Prairie hay	9.19	5.63	2.13	30.50	8.87	43.68	2.6	48.5	2
	Corn	11.10	9.95	3.87	1.68	1.23	72.17	7.6	84.3	1
	Cottonseed Meal	8.43	42.28	6.24	9.46	6.39	34.86	34.2	72.2	—
1939–40	Alfalfa hay	11.17	17.00	2.48	25.62	8.92	34.81	12.2	49.8	2
	Corn	9.10	10.47	4.74	2.50	1.66	71.53	8.0	86.3	2
	Oats	10.23	11.62	4.36	8.84	3.49	61.46	9.1	70.8	2
	Barley	12.40	11.22	1.29	5.42	2.41	67.26	8.9	76.1	2
	Cottonseed Meal	3.97	43.80	6.34	8.54	6.47	30.88	35.5	76.0	—
1940–41	Alfalfa hay	10.65	19.01	2.79	20.60	9.85	37.10	13.7	50.9	2
	Corn	13.95	10.00	4.15	2.45	1.64	67.81	7.6	81.2	2
	Oats	10.48	11.96	4.32	10.10	4.04	59.10	9.3	69.6	2
	Barley	10.00	11.81	1.38	5.12	2.50	69.19	9.3	78.3	2
	Cottonseed Meal	7.84	42.56	6.94	8.62	5.48	28.56	34.5	74.6	—
1941–42	Alfalfa hay	10.35	15.44	2.74	29.10	7.74	34.63	11.1	50.2	2
	Corn	13.94	10.28	2.85	2.01	1.50	69.42	7.8	80.1	2
	Oats	9.66	11.42	3.74	10.65	3.89	60.64	8.9	69.5	2
	Barley	10.94	12.16	1.35	4.75	2.68	68.12	9.6	77.4	2
	Cottonseed Meal	8.95	42.94	6.59	9.10	6.62	25.80	34.8	72.3	—

[1] Analysis made by Agricultural Chemistry Department of the Oklahoma Experiment Station.
[2] Calculated by using the digestion coefficients of Morrison (1936).

amount of cottonseed meal was added to insure an adequate supply of protein in all lots, as a slight variation naturally existed in the composition of the grains.

Lot Ia was used as the check lot in feeding. The lambs in this lot were fed slightly less than a full feed so that they would always clean up their feed despite the temperature.

The feeds used in all three years of the second series of experiments were produced in normal years. Their chemical analysis, market grades, calculated digestible protein, and T.D.N. content are given in table 1.

Experimental Results

The chemical composition of the feeds used in the six feeding experiments are given in table 1.

TABLE 2.—A THREE-YEAR COMPARISON OF THE VALUE OF FEEDS FOR FATTENING LAMBS

Lot No.	I	II	III	IV	V	VI
Ration	Corn C.s.m. Alf. hay	Corn Alf. hay	Corn C.s.m. Alf. hay	Corn C.s.m. Pr. hay Gr. limestone	Corn C.s.m. Alf. hay	Corn C.s.m. Alf. hay Pr. hay Gr. limestone
No. lambs in lot	57[1]	60	60	59[2]	60	58[3]
Days on feed	96.3	96.3	96.3	96.3	96.3	96.3
Av. initial wt.	62.6	62.2	62.3	62.3	62.3	62.6
Av. final wt.	94.1	93.2	92.8	89.1	90.0	89.6
Av. daily gain	.33	.32	.32	.28	.29	.28
Av. daily feed						
Corn	1.16	1.25	.58	.97	.97	.97
Cottonseed meal	.10	—	.75	.33	.33	.33
Alfalfa hay	1.17	1.17	1.17	—	.92	.29
Prairie hay	—	—	—	1.00	—	.77
Gr. limestone	—	—	—	.03	—	.03
Feed per cwt. gain						
Corn	355.6	387.2	184.1	348.5	337.5	346.1
Cottonseed meal	30.4	—	237.3	118.2	114.5	117.5
Alfalfa hay	361.8	362.3	367.9	—	321.7	104.0
Prairie hay	—	—	—	361.0	—	273.2
Ground limestone	—	—	—	10.8	—	10.7
Salt	6.6	5.9	6.3	7.3	8.4	7.7
Mineral	3.2	2.9	2.9	4.3	3.9	2.9
Av. warm dressing %	48.6	48.3	49.1	46.1	48.8	47.6
Av. carcass grade	3.7	3.6	3.6	3.5	3.6	3.4

[1] Two lambs died and one lamb was removed.
[2] One lamb removed.
[3] One lamb died and one removed.

One concentrate can be chosen as a standard, and other concentrates compared to it. The value of a roughage may be expressed in terms of a standard roughage. The two feeds chosen as standards in this study were corn and alfalfa hay. Morrison (1936) gives the estimated net energy of No. 2 shelled corn as 79.2 therms per hundred pounds. The shelled corn used in the first trial actually graded No. 5 by the Bureau of Agricultural Economics of the United States Department of Agriculture because of the large number of damaged kernels. The corn was very similar in chemical composition to the No. 2 corn used the other years. All samples had a higher protein content than Morrison specifies for No. 2 corn. The same author gives the estimated net energy of alfalfa hay, with fiber content similar to the hay used in these trials, as 41.5 therms per hundred pounds. These values were used in the energy calculations that are presented in this paper.

The Relative Value of Corn and Cottonseed Meal. It was impossible to get all lots of lambs to gain exactly the same total number of pounds, and consequently there were small variations in the feed per hundred pounds gain even though an effort was made to keep them constant.

One cannot get a true net energy value of cotton seed meal by comparing lots II and III. The first year .1 pound of cottonseed meal fed to lot I improved the efficiency of the ration. A part of this higher value secured in comparing lots II and III must therefore be due to the improvement of the ration by adding the first .1 pound of cottonseed meal. While comparing these lots does not give a true net energy value, the comparison is not without interest from the standpoint of the commercial lamb feeder. A similar high value or supplement value for .1 pound of cottonseed meal did not exist in feeding similar rations in 1937–38 and 1938–39 which contained appreciably more protein.

The method of Morrison (1937) was used in making calculations. The calculated values of cottonseed meal fluctuated from year to year, but in only one year did the calculated value from these feeding experiments equal the calculated value of Fraps' for ruminants or Morrison's value. No value was secured that approached Armsby's value or Fraps' for lambs, calculated from lamb feeding experiments.

Dressing percentages of the three lots of lambs (table 2), were similar. The average carcass grade of the lambs should be a fairly reliable index of fat covering on the carcass because of the similarity of the lots in size, weight, and conformation. These grades (table 2) show that the packer grader did find some slight variations in the finish of the carcasses. If any actual difference in carcass covering existed, it can be stated that on the average lots II and III had similar carcass covering while lot I carcasses tended to carry more finish. These data indicate that while the goal of having comparable

finish on the carcasses was at times approached, the aim was never actually achieved. These discrepancies would, if proper credit were given, lower the calculated values of cottonseed meal when fed in excess of the supplementing level of .1 pound (lots I and III) per day when added to a ration of corn and alfalfa hay.

In commercial feeding, palatability is a factor that cannot be overlooked. The lambs in lot III that were fed the high allowance of cottonseed meal

TABLE 3.—THE NET ENERGY VALUE OF COTTONSEED MEAL (IN THERMS) AS CALCULATED FROM LAMB FATTENING EXPERIMENTS USING CORN AS A BASE FEED

Lot Comparison	Experimental (3 yrs.)	Comparison Values			
		Armsby	Fraps		Morrison
			Lambs	Ruminants	
I and II	64.4	93.5	100.7	73.5	74.2
II and III	66.8				

were usually fed about the maximum amount of feed they would consume. Lot I, in particular, would have taken more concentrates had they been offered. Under the plan of experiment they were limited in their intake so that the other lots might have approximately the same average daily and total gain during the experiment. Because of this procedure, it is reasonable to assume that the large amount of cottonseed meal had a higher calculated value, as compared to corn, than might be expected in actual commercial feeding practice.

The Relative Value of Alfalfa Hay and Prairie Hay. The second phase of the first series of experiments dealt with the comparative value of alfalfa and prairie hays for fattening lambs and the results are given in table 2. Lots IV and VI received .25 ounce of finely ground limestone per head daily to make up for the calcium deficiency of prairie hays.

The hays in those lots were always fed at such a level that the lambs receiving the prairie hay were consuming the maximum amount of hay they would clean up without waste. Lot V would have consumed more hay readily, but the lambs in this lot were allowed only enough hay to keep them gaining at nearly the same rate as the lambs in lot IV. Lot VI received .3 pound of alfalfa hay per head, and in addition received the amount of prairie hay necessary to keep the lot gaining at approximately the same rate as lots IV and V.

The prairie hay used in 1936–37 was somewhat coarse, had few leaves, was rather dark in color, and appeared to have been weathered. It was

graded No. 3 by the Bureau of Agricultural Economics of the United States Department of Agriculture. The hay was surprisingly palatable to the lambs. The other feeds used in the study of the value of the two hays were the same as those used in the first mentioned part of this investigation.

From the data given in table 2 the calculated net energy value of prairie hay given in table 4 was made.

The calculated value of prairie hay resulted in considerable variation as compared to the alfalfa hay which served as a basis for comparison. In the first experiment a combination of prairie and alfalfa hay gave decidedly poor economy as compared to either hay alone. In the second year the combination

TABLE 4.—THE NET ENERGY VALUE OF PRAIRIE HAY (IN THERMS) AS CALCULATED FROM LAMB FATTENING EXPERIMENTS, USING ALFALFA HAY AS A BASE FEED

Lot Comparison	Experimental (3 yrs.)	Comparison Values			
		Armsby	Fraps		Morrison
			Lambs	Ruminants	
IV and V V and VI	33.8 29.8	40.4	28.3	36.9	36.9

worked well together, but in the third year, it again took more total pounds of hay to keep the lambs gaining at the desired rate than when either hay was used separately.

It is surprising that the value of the same prairie hay should have been calculated approximately 5 therms lower in 1938–39 than the preceding year. Admittedly, the alfalfa hay used was not the same and was higher in protein than that used the year before. The color of the alfalfa hay was not as good and it graded two grades lower; the lambs, however, found the hay exceedingly palatable. This alfalfa hay may have had a higher actual net energy value for fattening lambs than the higher grading hay used the previous year. The only nutrient that would be expected to alter gain that might have d sappeared in the storage of the prairie hay is vitamin A. Despite the magnitude of this decrease, the work of Braman and coworkers (1935) with rats would not lead one to expect such a decrease in the feeding or energy value.

Dressing percentage failed to be a good criterion of carcass increase in the roughage study, as it had likewise failed in the comparison of corn and cottonseed meal.

In all three years of the study the alfalfa-fed lambs in lot V had to be held back throughout most of the feeding period so that comparable gains could

be secured in lots IV and VI receiving the prairie hay. It was found advisable to feed the alfalfa hay to lot VI on top of the prairie hay in a feeder with a solid front. In this manner wastage of the prairie hay was kept at a minimum. There was apparently no nutritive factor present in the .3 pound alfalfa hay fed lot VI that made the ration more efficient than when prairie hay made up the sole roughage allowance.

TABLE 5.—A THREE YEAR SUMMARY OF THE RESULTS OF FEEDING CORN, OATS, AND BARLEY TO FATTENING LAMBS

Lot Number	Ia	IIa	IIIa	IVa	Va	VIa
Ration	Corn C.s.m. Alf. hay	Oats C.s.m. Alf. hay	Barley C.s.m. Alf. hay	Corn Oats C.s.m. Alf. hay	Corn Barley C.s.m. Alf. hay	Oats Barley C.s.m. Alf. hay
No. lambs in lot	60	60	60	60	60	60
Av. No. days fed	99.3	99.3	99.3	99.3	99.3	99.3
Av. initial wt.	64.9	65.0	64.9	64.9	64.9	64.9
Av. final wt.	96.7	96.4	96.1	97.1	96.1	95.8
Av. daily gain	.32	.32	.31	.32	.31	.31
Av. daily feed						
Corn	1.16	—	—	.58	.58	—
Oats	—	1.24	—	.60	—	.58
Barley	—	—	1.27	—	.67	.68
Cottonseed meal	.10	.10	.10	.10	.10	.10
Alfalfa hay	1.32	1.32	1.32	1.32	1.32	1.32
Feed per cwt. gain						
Corn	363.4	—	—	179.3	185.3	—
Oats	—	391.8	—	185.4	—	186.8
Barley	—	—	404.4	—	212.8	219.8
Cottonseed meal	31.3	31.7	31.8	30.8	31.9	32.1
Alfalfa hay	411.6	416.8	418.9	406.1	419.9	423.1
Salt	5.5	5.6	5.3	5.1	5.5	5.7
Mineral	1.0	1.1	.9	1.0	.9	1.1
Av. warm dressing %	49.9	49.5	49.7	48.7	49.9	49.2
Av. carcass grade	3.67	3.40	3.40	3.55	3.67	3.50

The Relative Values of Corn, Oats, and Barley. The summary of results secured in three lamb fattening experiments in which corn was replaced entirely or partially by oats and barley is given in table 5.

The Relative Value of Corn and Oats. The calculated net energy value of oats is given in table 6. These values are high as compared to the values shown in the table for comparison. The value for 1941–42 was extremely high (100.1 therms) when oats replaced one-half the corn in the ration of lot

IV. This value was no doubt so high because of the great fill made by these lambs in the last two weeks of the feeding period. The lambs shrank the least of any lot en route to market, and the low dressing percentage they had was no doubt due to this combination of conditions Their advantage over the other lots in total and average daily gain came in the later stages of the feeding period.

TABLE 6.—THE NET ENERGY VALUE OF OATS (IN THERMS) AS CALCULATED FROM LAMB FATTENING EXPERIMENTS USING CORN AS A BASE FEED

Lot Comparison	Experimental (3 years)	Comparison Values			
		Armsby	Fraps		Morrison
			Lambs	Ruminants	
Ia and IIa	72.8	67.6	73.3	72.2	64.9
Ia and IVa	80.1				

The calculated values for oats as compared to corn are too high when live weight gain is used as a basis of computation. In none of the three feeding experiments did the lambs in lot IIa, fed oats as the only grain, have the carcass finish of lot Ia. When the two grains were used together in lot IVa, the carcass grade was improved two of the three years. The lambs in lot Ia would have taken more grain all of the time and lot IVa would usually have taken some increase. These lambs had to be kept at less than full-feed because some other lots in the study could not eat the feed required for more rapid gains. Lot IIa would not have taken much more grain because of the bulky nature of the ration.

The Relative Value of Corn and Barley. Whole barley did not compare as favorably with corn as did oats in making live weight gains on fattening lambs. The calculated values of the barley from the various comparisons of corn and barley are summarized in table 7.

TABLE 7.—THE NET ENERGY VALUE OF BARLEY (IN THERMS) AS CALCULATED FROM LAMB FATTENING EXPERIMENTS USING CORN AS A BASE FEED

Lot Comparison	Experimental (3 years)	Comparison Values			
		Armsby	Fraps		Morrison
			Lambs	Ruminants	
Ia and IIIa	70.3	89.9	74.7	74.4	70.5
Ia and Va	64.5				

While barley did not match corn in making live weight gains on fattening lambs, the combination of corn and barley fed lot Va was the only grain replacement or combination of grains used in the study that resulted in carcass finish equal to the corn fed lambs of lot Ia. It thus appears that energy storage was at least very similar. Barley fed as the only grain resulted each year in carcasses that graded lower than lambs similarly fed corn. Consequently, the values for barley given in table 7 in comparing lots Ia and IIIa are higher than they should be when the finish produced is considered. Live weight gain was not a safe criterion of energy storage in such an instance.

The Relative Value of Oats and Barley. In producing live weight gains on fattening lambs, barley did not prove equal to oats under the conditions of these experiments. In only the last year of the three-year study did a combination of barley and oats prove as effective in economy of gain as either grain fed alone. In this trial the barley in the combination exceeded by .1 therm the value of 74.1 therms calculated for oats in these experiments. The value of barley calculated in terms of oats is given in table 8. The values calculated by using Morrison's estimated oat value of 64.9 therms are also given.

TABLE 8.—THE NET ENERGY VALUE OF BARLEY (IN THERMS) AS CALCULATED FROM LAMB FATTENING EXPERIMENTS USING OATS AS A BASE FEED

Lot Comparison	Experimental (3 years)	Comparison Values			
		Armsby	Fraps		Morrison
			Lambs	Ruminants	
IIa and IIIa[1]	70.3	89.9	74.7	74.4	70.5
IIa and VIa[1]	66.6				
IIa and IIIa[2]	62.6				
Ia and VIa[2]	59.2				

[1] Using three year lot II Oat Value of 74.1.
[2] Using Morrison's (1936) oat value.

During the three years the lambs fed the combination of corn and barley averaged higher carcass grades than when either grain was fed alone; this resulted mainly from the superiority of the carcasses the third year of the study. Carcasses produced from barley fed as the only grain carried on the average the same finish as when oats was used as the only grain. A comparison of barley with corn and with oats usually resulted in lower values in these experiments than the values given in tables 7 and 8 for comparison. These same authors have all assigned a higher net energy value to barley than they have to oats; the results of this study would not confirm these appraisals of these two feeds for fattening lambs.

Barley had a higher calculated value when compared to corn as a base feed than when compared to oats (tables 7 and 8), although the base value of oats used was determined from a comparison with corn. This difference cannot be attributed to difference in condition of the lambs, as oats and barley lambs graded approximately the same and were both inferior to the corn lambs with which they were compared.

Discussion

The experiences encountered in these experiments are similar to those of two other investigations using a similar method of studying the comparative energy values of feeds by controlled feed lot gains with fattening lambs. Leinbach (1940) studied the relative net energy values of corn grain and alfalfa hay and of sorghum fodder and alfalfa hay. In his experiments the same or similar live weight gain resulted in considerable difference in carcass finish. He attempted to adjust his energy values, based on live weight gain, to account for differences in carcass finish. Considerable difference in the value of alfalfa was found depending on the level of feeding. Cairns (1940) studied the relative net energy values of distiller's corn dried grains and brewer's dried grains as compared to corn grain. Two years' results differed greatly in the value of these feeds in replacing corn in the ration of lambs making the same live weight gain. Great differences in carcass finish were encountered in lambs making the same live weight gain.

Fraps and Carlyle (1937) studied the energy intake, live weight gain, and energy storage of chicks on various rations. They concluded that the amount of feed required per unit of gain was not a good indication of its energy value, though it may be a practical measure of a ration for animals sold on a live weight basis. They did not find equal live weight gain resulted in equal energy storage.

The experiences with controlled live weight gains as a method of estimating net energy values of feeds indicate that several considerations make the results so secured unsuitable to be called net energy values. They are in reality values expressing the live weight gain that can be produced from one feed in terms of a given feed. Forbes' (1937) suggestion that such values be referred to as "live weight production values" is probably as descriptive a name for such values as any suggestion thus far made.

In these experiments several factors suggested themselves as unfavorable considerations in the use of controlled live weight gains to express the nutritive value of feeds. Some of these factors are as much or more inherent in a ordinary feed-lot comparison as they are in the type of study that was conducted.

In the first place, the same live weight gain in two lots may not always

mean comparable finish of the carcasses. In such cases there is little doubt that comparable energy storage was not obtained because fat carries more energy than other increases that might occur.

Live weight increase is greatly influenced by the weather in a feed lot trial. Weather changes may cause a lot to fill or shrink and hence alter what would have been a normal gain. All lots do not react the same to these changes in environment. The effect of weather is most marked at the beginning or close of the trial because of the importance of these weights in calculations. Unequal fill or shrink between lots will result in a distorted live weight gain, shrinkage, or dressing percentage and make these of little value for comparative purposes.

This method does not give full expression to the important factor of palatability. The greater the difference in palatability, the more overrated the less liked feed becomes by comparison. Because of the unpalatability of feeds, it is not always possible to get lambs to consume enough of a certain feed to gain rapidly enough for satisfactory commercial production.

An error in the assumed value of base feeds will result in an inherent error in all calculated values. It is difficult to get experimental feeds that are exactly alike in market grade, chemical composition, and palatability, to say nothing of unforeseen factors that may cause a change in nutritive value. As a result, values are calculated from a changing rather than from a constant base value. One of these considerations, or an accumulation of them, results in an inability to duplicate results from year to year; e.g. two experiments using the same prairie hay gave a difference of 5.1 therms in the calculated net energy values of the hay.

Magnification of small and probably insignificant difference can easily result when all the difference in performance between two rations is credited to the value of one particular feed. After experience in equalizing gains by controlled feed intake, one realizes that the human element of necessity functions in determining how successfully gains are controlled. Certain rations produce gains readily early in the feeding period, but tend to drop behind as the experiment proceeds. An oats and alfalfa hay ration seemed to exhibit this characteristic. Experience one year may help to keep gains more nearly matched another. Ration combinations, according to Forbes and associates (1933), alter the net energy value of a feed. This condition was apparently encountered when a value for oats was calculated from a comparison of its value with corn, and then used as a basis for evaluating barley.

Several advantages can be suggested for an experimental procedure such as used in these studies. In many feeding experiments gains are not controlled. It has been demonstrated that very similar gains can be secured on feeds that are similar in nature and consequently a wide difference in live weight gain

does not exist when the results of an experiment are summarized. This, in itself, removes one variable that is common in many feeding experiments in which no attempt is made to secure similar performance. This method reduces uncontrolled factors common in many studies because only one known variable exists between two lots.

Calculating the comparative value of a feed in terms of only one base feed is an advantage not to be overlooked in conveying experimental information to the public. The value of oats in terms of its relationship to corn is probably easier for the feeder to understand than to relate its feeding value in terms of corn plus or minus the amount of cottonseed meal and alfalfa hay required for similar production of market weight. Very often investigators work out the comparative values of feeds by using assumed feed prices or prices then existing. Such comparative feeding values change each time the price relationship of the feeds changes.

Expressing other feeds in terms of a base feed should not be considered a net energy value in light of present information. Expressing feeds in terms of their value as compared to corn, alfalfa, or other accepted standard feeds can be a distinct contribution in dispensing experimental information. A standardization of method in calculating and expressing the comparative value of feeds should serve to enlighten the public for whom such information is obtained.

The controlled gain plan of conducting feeding experiments suggested by Morrison (1937) removes enough of the variables from such experiments to be worthwhile. This is particularly true of feeds similar in physical and chemical nature as well as palatability.

Summary

Thirty-six lots of twenty lambs each were fed during a six-year period by a controlled gain method. An attempt was made to establish the relative net energy value of cottonseed meal, barley, oaks, and prairie hay for fattening lambs, using corn and aldalfa hay as base feeds.

In the first series of experiments, covering a three-year period, cottonseed meal fed in excess of the amount needed to balance the ration had an average value of 64.4 therms per hundred pounds in producing live weight gain on lambs, based on an assigned value of 79.2 therms for corn. In one of three experiments, .1 pound of cottonseed meal added to a ration of corn and alfalfa had considerable supplementing value. The net energy values of prairie hay varied widely, but averaged 33.8 therms, based on the value of 41.5 therms assigned alfalfa hay.

A second series of experiments, conducted in three successive years, found oats to have an average value of 72.8 therms when they replaced all the corn

in a ration of 80.1 therms when one-half the corn was replaced. These values are based on live weight gains and do not consider the less finished carcasses of the oat-fed lambs. In a similar comparison barley had an average value of 70.3 therms in replacing all the corn or 64.5 therms in replacing one-half the corn. Carcasses of lambs fed corn and barley carried as much carcass finish as corn-fed lambs, but barley alone did not produce comparable finish. The value for barley was slightly higher when fed in combination with corn than when fed with oats.

Results of these experiments suggest that comparable live weight gains commonly do not result in similar carcass condition of experimental lambs. Other factors encountered in controlling gains of lambs that may have biased the values obtained are weather, fill, feed quality, palatability, rate of gain, base values of feeds, feed combinations, and the inability of the experimenter to always keep lots gaining at or near the same rate.

The described method of evaluating feeds does reduce the number of variables common to ordinary feeding experiments because gains are controlled as is the intake of all feeds except those under comparison. The live weight gain producing value of a feed can be expressed readily in terms of a standard or base feed with which it was compared.

Literature Cited

Armsby, H. P. 1917. The Nutrition of Farm Animals. The Macmillan Co., New York.

Armsby, H. P., and J. A. Fries. 1903. The Available Energy of Timothy Hay. U. S. Dept. of Agr., Bur. of Anim. Indus. Bul. 51.

Armsby, H. P., and J. A. Fries. 1915. Net Energy Value of Feeding Stuffs for Cattle. Jour. Agr. Res. 3: 435–491.

Braman, W. W., A. Black, O. J. Kahlenberg, L. Voris, R. W. Swift, and E. B. Forbes. 1935. The Utilization of Energy-Producing Nutriment and Protein in White and Yellow Corn and in Diets Deficient in Vitamins A, D, and G. Jour. Agr. Res. 50: 1–37.

Brody, S., and R. C. Proctor. 1933. Growth and Development XXXI Influence of the Plane of Nutrition on the Utilizability of Feeding Stuffs. Mo. Agr. Expt. Sta. Res. Bul. 193.

Cairnes, M. C. 1940. The Use of Lamb Fattening Experiments in Determining the Relative Net Energy Values of Distiller's Corn Dried Grains and Brewer's Dried Grains in Comparison with Corn Grain. Doctorate Thesis, Cornell Univ.

Forbes, E. B. 1933. The Law of Maximum Normal Nutritive Value. Science 77: 306–307.

Forbes, E. B. 1929. The Problem of Determination of Net Energy Values of Feeding Stuffs. Am. Jour. Physiol. 90: 348. (Abs. 13th Int. Physiological Congress).

Forbes, E. B. 1937. Discussion of the Papers of G. S. Fraps and F. B. Morrison. Amer. Soc Anim. Prod. Proc. 30: 27–29.

Forbes, E. B., W. W. Braman, Max Kriss, R. W. Swift, R. B. French, C. V. Smythe, P.S. Williams, and H. H. Williams. 1930. Further Studies of the Energy Metabolism of Cattle in Relation to the Plane of Nutrition. Jour. Agr. Res. 40: 37–78.

Forbes, E. B., and Max Kriss. 1925. Revised Net-Energy Values of Feeding Stuffs for Cattle. Jour. Agr. Res. 31: 1083–1099.

Forbes, E. B., Max Kriss, and R. C. Miller. 1934. The Energy Metabolism of the Albino Rat in Relation to the Plane of Nutrition. Jour. Nutr. 8: 535–552.

Forbes, E. B., R. W. Swift, Alex Black, and O. J. Kahlenberg. 1935. The Utilization of

Energy Producing Nutriment and Protein as Affected by Individual Nutrient Deficiencies. III. The Effects of the Plane of Protein Intake. Jour. Nutr. 10: 461–479.

Forbes, E. B., L. Voris, J. W. Bratzler, and W. Wainio. 1938. The Utilization of Energy Producing Nutriment and Protein as Affected by the Plane of Nutrition. Jour. Nutr. 15: 285–307.

Fraps, G. S. 1931. Productive Energy of Feeds Calculated from Feeding Experiments with Sheep. Texas Agr. Expt. Sta. Bul. 436.

Fraps, G. S., and E. C. Carlyle. 1939. Relation of gain in weight to gain in energy content of growing chickens. Jour. Agr. Res. 59: 777–781.

Guilbert, H. R., and G. H. Hart. 1937. Relationship of Accessory Factors and Requirements of Feed Values. Amer. Soc. Anim. Prod. Proc. 30: 42–48.

Hamilton, T. S. 1937. The Influence of the Percentage of Protein upon the Thermogenic (Specific Dynamic) Effect and the Net Energy of the Diet. Proc. Amer. Inst. Nutr. 1937. Jour. Nutr. 13 (1937) Suppl. P. 16.

Hart, E. B. 1937. The Guiding Principles for Nutrition Research. Amer. Soc. Anim. Prod. Proc. 30: 48–50.

Henry, H. A., and F. B. Morrison. 1915. Feeds and Feeding, 15th ed., Henry and Morrison Co., Madison, Wisc.

Johnson, S. R., A. G. Hogan, and U. S. Ashworth. 1936. The Utilization of Energy at Different Levels of Protein Intake. Mo. Agr. Expt. Sta. Res. Bul. 246.

Kahlenberg, O J., A. Black, and E. B. Forbes. 1937. The Utilization of Energy Producing Nutriment and Protein as Affected by Sodium Deficiency. Jour. Nutr. 13: 97–108.

Kellner, O. 1905. Die Ernahrung der Landwistschaftlichen Nutztiere. Paul Parey Co., Berlin.

Kleiber, Max, Harold Goss, and H. R. Guilbert. 1936. Phosphorus Deficiency Metabolism and Food Utilization in Beef Heifers. Jour. Nutr. 12: 121–153.

Kriss, Max. 1938. The Specific Dynamic Effects of Proteins When Added in Different. Amounts to a Maintenance Ration. Jour. Nutr. 15: 565–581.

Leinbach, F. H. 1940. The Relative Net Energy Values of Alfalfa Hay and Corn Grain and of Sorghum Fodder and Alfalfa Hay as Determined by Feeding Experiments with Fattening Lambs. Doctorate Thesis, Cornell Univ.

McClure, F. J., Le Roy Voris, and E. B. Forbes. 1934. The Utilization of Energy Producing Nutriment and Protein as Affected by Individual Nutrient Deficiencies. II. The Effects of Vitamin B Deficiency. Jour. Nutr. 8: 295–308.

Mitchell, H. H. 1937. The Importance of the Relations Between Energy, Protein, and Minerals in Measuring the Nutritive Value of Feeds and Rations. Amer. Soc. Anim. Prod. Proc. 30: 29–42.

Mitchell, H. H., and T. S. Hamilton. 1941. The Utilization by Calves of the Energy Contained in Balanced Rations Composed of Combinations of Different Feeds. Jour. Nutr. 22: 541–552.

Mitchell, H. H., T. S. Hamilton, F. J. McClure, and W. T. Haines. 1940. The Utilization by Calves of Energy in Rations Containing Different Percentages of Protein and in Glucose Supplements. Jour. Agr. Res. 61: 847–864.

Mitchell, H. H., T. S. Hamilton, F. J. McClure, W. T. Haines, J. R. Beadles, and H. P. Morris. 1932. The Effect of the Amount of Feed Consumed by Cattle on the Utilization of its Energy Content. Jour. Agr. Res. 45: 163–191.

Mitchell, H. H., W. G. Kammlade, and T. S. Hamilton. 1928. Relative Energy Value of Alfalfa, Clover, and Timothy Hay for the Maintenance of Sheep. Ill. Agr. Expt. Sta. Bul. 317.

Morrison, F. B. 1936. Feeds and Feeding, 20th ed. The Morrison Publishing Co., Ithaca, New York.

Morrison, F. B. 1937. Determining Net Energy Values by Means of Feeding Experiments. Amer. Soc. Anim. Prod. Proc. 1937. 30: 12–20.

Morrison, F. B., and G. W. Salisbury. 1934. Value for Dairy Cows of Early Cut Timothy Hay Fertilized with a Nitrogenous Fertilizer. N. Y. (Cornell) Expt. St. Ann. Rept. 47: 74–75.

Ritzman, E. G., and F. G. Benedict. 1930. The Energy Metabolism of Sheep. New Hampshire Agr. Expt. Sta. Tech. Bul. 43.

Ritzman, E. G., and F. G. Benedict. 1931. The Heat Production of Sheep under Varying Conditions. N. H. Agr. Expt. Sta. Bul. 45.

Ritzman, E. G., and F. G. Benedict. 1934. N. H. Agr. Expt. Sta. Ann. Rept. Bul. 284. p. 11–12.

Ritzman, E. G., and F. G. Benedict. 1931. N. H. Agr. Expt. Sta. Ann. Rept. Bul. 262, p. 11–12.

Swift, R. W., O. J. Kahlenberg, Le Roy Voris, and E. B. Forbes. 1934. The Utilization of Energy Producing Nutriment and Protein as Affected by Individual Nutrient Deficiencies. I. The Effects of Cystine Deficiency. Jour. Nutr. 8: 197–219.

Watson, J. A. S., D. Skilbeck, and J. C. B. Ellis. 1937. Experiments on the Relation of Energy Intake to Live Weight Increase in Fattening Sheep. Empire Jour. Expt. Agr. 5: 180–188.

Zuntz, N., and O. Hagemann. 1898. Landw. Jahrbücher, Vol. 27, Sup. III.

ABSTRACTS OF PAPERS TO BE PRESENTED AT THE THIRTY-SIXTH ANNUAL MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

The meetings will be held at the Hotel Sherman in Chicago, Illinois, on November 30 and December 1, 1943. The programs of the general sessions will be devoted to discussions of the ways in which animal husbandry work can best serve the war effort and the adjustments that will have to be made in the post-war period. Abstracts exceeding the 250-word limit have been arbitrarily reduced by the Editor since the limited time for getting them to the printer makes it impossible to return them to the authors for correction.

Animal Breeding Section

G. E. Dickerson, *Chairman*

ASCORBIC ACID—GONADOTROPIC HORMONE RELATIONSHIPS. John O. Almquist and Frederick N. Andrews, *Purdue University Agricultural Experiment Station.*

During the past decade evidence has been accumulating concerning the rôle of ascorbic acid in the regulation of the normal reproductive processes and the endocrine relationships of vitamin C utilization. In sexually mature male and female cattle and steers the injection of equine gonadotropin results in a marked reduction of blood plasma ascorbic acid. Since the gonadotropic hormones regulate normal reproduction the objective of this experiment was to determine whether or not the injection of ascorbic acid would increase the effectiveness of equine gonadotropin. A total of 199 rats were observed. The simultaneous injection of 50 mg. of ascorbic acid and 25 R.U. of pregnant mare serum gonadotropin in 24 day-old rats for 4 days and in 70 day-old rats for 20 days produced no greater increase in the weight of the testes, ovaries or uterus than did the injection of 25 R.U. of gonadotropin alone.

EFFECTS OF PITUITARY GONADOTROPINS UPON CYSTIC OVARIES AND NYMPHOMANIA IN COWS. L. E. Casida, W. H. McShan and R. K. Meyer, *University of Wisconsin.*

An unfractionated extract of sheep anterior pituitary gland was injected intravenously into 96 cows with cystic ovaries. Eighty-one of these animals showed nymphomania originally but the symptoms disappeared in 72 after a single injection. Symptoms recurred during the observation period in 14 of them. Six of these recurrences were from the 12 animals that showed uterine or tubal pathology. Corpora lutea are known to have been formed in 74 of the 96 animals within 31 days after treatment. Normal estrus has been shown by 69 of them since the single injection. Of the 52 animals bred out of 84 showing no recognized uterine or tubal pathology, 35 have become pregnant.

A COMPARISON OF THE EFFECTS OF INBREEDING AND SELECTION ON PERFORMANCE IN SWINE. R. E. Comstock and L. M. Winters, *Minnesota Agricultural Experiment Station.*

The extent to which the loss of vigor ordinarily accompanying inbreeding can be offset by selection was studied using data on inbred lines of swine being developed in cooperation with the Regional Swine Breeding Laboratory. Litter size and average daily gain were con-

sidered. Intra line, intra farrow regressions on inbreeding were used to estimate the average decreases in these characteristics to be expected from inbreeding in the absence of selection. The increase per generation expected to result from selection in the absence of inbreeding were estimated from the actual selection differentials attained and published estimates of heritability. The data indicate that in the early stages of inbreeding the amount of selection practised in these lines would be sufficient to offset the effects of approximately 15 per cent inbreeding per generation in the case of growth rate and 2½ per cent in the case of number of pigs per litter. As the amount of inbreeding increases the heritability and, therefore, the effect of selection decreases. The theoretical and actual results are in reasonable agreement. The inbreeding practiced has averaged about 9 per cent per generation. Together with the selection practiced, this should and did result in increased growth rate and decreased litter size. It is concluded that fertility is much more difficult to maintain in lines of swine being inbred than is growth rate and, therefore, that everything possible should be done to make selection for fertility more effective.

CHANGES IN HOG CARCASSES ASSOCIATED WITH GENETIC SUPERIORITY IN ECONOMY OF GAIN. G. E. Dickerson, *U. S. Department of Agriculture and Iowa Agricultural Experiment Station.*

The association of rate of growth and feed utilization with carcass yields and measurements at a 225 pound live weight was analyzed. Genetic and environmental correlations were calculated from covariance analyses between sire progenies within season and line of breeding, between litters within sires and between litter mates. Data were for 501 Poland China, 108 Danish Landrace and 54 crossbred Poland-Landrace pigs from Record of Performance litters fed in dry lots at the Iowa station. Genetic superiority in growth rate and feed requirements from weaning to final weight was found to be significantly correlated with thicker backfat and larger yield of fat but with smaller yield of lean and shorter legs at 225 pounds. Correlations of these carcass traits with weight at 180 days were similar but smaller. Also, observed genetic variation in yield of fat greatly exceeded that in yield of lean. This tendency for fat deposition to outstrip growth of muscle and bone in pigs which are genetically superior in growth and feed utilization suggests that genetic improvement in economy of gain is likely to mean fatter carcasses at a live weight of 225 pounds. Selection against excessive fatness would reduce the trend toward fatter carcasses but would also make selection for economy of gain less effective.

ON THE PHYSICAL BASIS OF TYPHOID RESISTANCE. John W. Gowen, *Iowa State College.*

Our studies on typhoid, *Salmonella typhimurium*, in mice have created 6 inbred lines characterized in part by differences in disease resistance. Ba and L lines have but 8 and 13, E and Z 53 and 58, and R. I. and S lines 75 and 86 per cent survive on inoculation with 200,000 bacteria. Analyzing these strains for factors leading to this variability in resistance shows characteristic leucocyte numbers for each strain. High leucocytes are found in resistant strains, intermediate in less resistant and low in susceptible strains. On the humeral side bacteriocidins are not found in the blood of any of these strains. Capacity to immunize passively through vaccination or actively through previous contact with disease, however, differs from strain to strain. Here slight shifts in order take place, R. I., S. and Z have marked capacity for immunization, E much less and Ba and L least. But bacteria also have genotypes. Three such types have been isolated through mutation or otherwise. These types are highly virulent, medium virulent, and avirulent. Toxicity of these bacterial lines to mouse strains is in the same direction as indicated earlier but at different levels. Capacity for producing immunity through vaccination is markedly different between bacterial lines and mouse strains. As these differences are all clearly under gene control, it becomes evident that typhoid resistance has its physical basis in interactions of genotypes of hosts and pathogens, these interactions expressing themselves over the full range of the disease defence mechanism.

THE EFFECT OF SEX ON THE DEVELOPMENT OF THE PIG IV. HISTOLOGICAL AND ENDOCRINOLOGICAL STUDIES OF THE BOAR. W. W. Green and L. M. Winters, *University of Minnesota.*

Lines of inbred swine developed at the University of Minnesota have exhibited differences in age of puberty and virility. Sexual development of some lines has been studied by histological studies of the testes as well as by urinary androgen excretion. Testicles were removed from boars at ages ranging from 8 to 28 weeks. The age and body weight of the boars; seminiferous tubular diameter; number of spermatogonial cells, primary and secondary spermatocytes, and spermatids; and the number and size of interstilial cells were studied. Testicular weight was more closely correlated with the body weight than the age of the boars. Testicular weight was a better measure of the internal development of the testes than was body weight or age, although body weight was equally good in the case of the number of spermatogonial cells and primary spermatocytes. Line differences were found in all instances except tubular diameters. Non-significant regressions were found in the case of interstitial cell diameters when compared with age, body or testicular weights. Urinary 17 Ketosteroid excretion was influenced by age, line, season, and urine quantity. From observations of the lines and individual boars, the age at which internal development of the testes took place was not always correlated with external signs of virility or with 17 Ketosteroid excretion. Just as sexual desire may be uncorrelated with the number and quality of sperm cells produced, it may be uncorrelated with androgen excretion because of factors modifying the expression of the male hormones.

MEASURING THE AMOUNT OF GENETIC CHANGE IN A HERD AVERAGE. Ronald H. Nelson, *Iowa State College.*

A herd average may change from one year to another, partly because the environment changes and partly because the genetic composition of the herd changes. To measure the latter change it is necessary to measure and discount the former. Two methods of doing this are illustrated, using the production records of the Holstein herd at the Iowa Station as an example. One method is simply to compute the average difference in production for all those cows which had records in consecutive years and to use this as the measure of the environmental change between those two years. The change between non-consecutive years is then computed as the algebraic sum of such differences between consecutive years. The second method is a least squares procedure which does essentially the same thing except that it minimizes errors in computing differences between years far apart and also uses the information in differences between records not made in consecutive years. The second method is longer and more complicated than the first. The two methods give approximately the same estimate for the difference between any two consecutive years. When the intervals between the years being compared are longer, the results of the two methods tend to diverge. The least squares method yields the more conservative estimate of environmental change. Which method to use in any actual case will depend on the volume of data, the accuracy desired, and the facilities for calculation.

HERITABILITY OF YEARLING FLEECE AND BODY TRAITS OF RANGE RAMBOUILLET EWES. Clair E. Terrill and Lanoy N. Hazel, *United States Department of Agriculture, Dubois, Idaho.*

Data were analyzed from 1622 daughter-dam pairs for yearling staple length, grease-fleece weight, clean-fleece weight, body weight, and scores for body type, face covering, neck folds, and body folds. Estimates of heritability were obtained by doubling the intra-sire, intra-year regression coefficients of daughter on dam. Differences in staple length appeared to be about 36 per cent heritable. Estimates for clean-fleece weight (for 2 years' data on 310 pairs and grease-fleece weight were 38 and 28 per cent respectively. The estimate for grease-fleece weight should be lower than that for clean-fleece weight because environmental variations in grease, dirt and moisture do not influence clean-fleece weight. Heritability was highest for body weight with an estimate of 40 per cent and lowest for body type score with an estimate

of 12 per cent. The low figure for the latter score is probably due to the composite nature and subjective method of measuring type. Scores for face covering, neck folds and body folds are more specific and objective than those for body type. This fact was supported by the estimates of heritability for the 3 traits which were 32, 26 and 32 per cent respectively. The regression coefficients were generally lower than the corresponding correlation coefficients because yearly variations were controlled for the daughters but only partially so for the dams. The heritability for traits of economic importance in range sheep seems to be sufficiently high that considerable genetic progress can be achieved by careful selection for these traits.

Beef Cattle Section

Bradford Knapp, Jr., *Chairman*

A STUDY OF GROWTH IN F1 HEREFORD X SHORTHORN HEIFERS. A. L. Baker *U. S. Range Livestock Experiment Station.*

In a study of growth records for 55 Hereford heifers from sire test herds and 53 F1 Hereford X Shorthorn heifers born in 1939 and 1940 and all out of random selected Hereford cows, it was found that the Crossbred heifers were significantly heavier at birth, weaning time and 18 and 30 months of age. The average weight at 30 months of age was 1137.7 pounds for Crossbred heifers and 1049.8 pounds for Hereford heifers. Differences between the two groups with respect to gains from birth to weaning corrected for age were statistically significant. The Hereford heifers were sired by five different Hereford bulls, while the Crossbred heifers were sired by two full-brother Shorthorn bulls.

BLUEGRASS AND ALFALFA SILAGES AS ROUGHAGES FOR FATTENING STEERS. W. P. Garrigus, *University of Kentucky.*

Digestion trials in triplicate have been completed in each of three consecutive years on bluegrass-molasses, alfalfa-molasses, and corn silages with yearling feeder steers receiving only one of the silages plus salt and water. Dry-matter intakes were held constant for the five-day preliminary and eight-day collection periods through use of the electrical quick drier (A.S.A.P. Proceedings 1937, pp. 354–361) for determining dry-matter content of the fresh silages before feeding. The alfalfa silages of all three years were made from early-bloom forage properly wilted and ensiled with addition of 50 to 60 pounds of blackstrap molasses per ton. These were found to contain 11.7, 13.7, and 13.0 per cent of digestible crude protein and 60.8, 61.1 and 65.3 per cent of total digestible nutrients on a dry basis. Bluegrass-molasses silages made respectively from fair, poor and good forage with addition of 40 to 50 pounds of blackstrap molasses per ton were found to contain 11.7, 6.0, and 15.3 per cent of digestible crude protein, and 71.6 58.5, and 75.2 per cent of total digestible nutrients respectively. Very good corn silages used for checks contained 5.6, 4.5, and 4.5 per cent of digestible crude protein and 68.4, 69.9, and 74.7 per cent of total digestible nutrients. Lots of ten steers each fed approximately 14 pounds of the grass silages and 4 pounds of first-cutting alfalfa hay plus a full feed of shelled corn produced gains in keeping with the results of these digestion trials.

THE VALUE OF CORN COBS IN A FATTENING RATION FOR STEER CALVES. Paul Gerlaugh, Wise Burroughs, L. E. Kunkle, *Ohio Agri. Expr. Sta., Wooster.*

Three lots of group fed calves, twenty head per lot, weighing about four hundred eighty pounds each, were started on the test in December and fed for two hundred and fifty-two days. Two pounds of soybean oil meal to which minerals had been added were fed daily per calf in all lots. Mixed clover and timothy hay was full fed to all lots. To one lot of calves ground shelled corn was fed, to another lot ground ear corn was fed, and to the third lot a corn-and-cob meal was fed which contained additional corn cobs. Average daily gains of 1.97 pounds, 1.99 pounds and 1.93 pounds were obtained. Selling prices and dressing percentages favored the larger portions of ground shelled corn in the grain ration though feed efficiencies favored

the larger portions of cobs. Three lots of individually fed calves twelve to the lot were used in a similar test, and showed results that were similar to the group fed cattle.

INTERRELATIONSHIPS OF SEMEN CHARACTERS AND EFFECT OF FREQUENCY OF EJACULATION ON SEMEN PRODUCTION IN YOUNG BEEF BULLS. I. Fred Roberts and Fred F. McKenzie. *Utah State Agricultural College, Logan, Utah.*

The interrelationships between several different semen evaluation scores were studied on 209 semen samples collected by the artificial vagina from eight young Hereford and Shorthorn bulls. Highly significant correlation coefficients were found between volume of ejaculation and semen color, volume of ejaculation and the number of attempts made by the bull before a successful ejaculation was completed color of the semen sample and concentration of the spermatazoa in the sample, viscosity of the sample and the concentration of the spermatazoa in the sample, viscosity of the sample and the color of the sample, motility of the spermatozoa and the concentration of the sample, barn temperature at time of collection and concentration of the spermatazoa in the sample, and lastly between the barn temperature at time of collection and the motility of the spermatazoa. A highly significant negative correlation coefficient was found between volume of ejaculate and pH of semen. A significant correlation coefficient was found between the volume of the ejaculate and the aggressiveness of the bull. Significant negative correlation coefficients were found between the motility of the spermatazoa and the pH of the semen, the concentration of spermatazoa in the sample and the pH of the sample, and lastly the aggressiveness of the bull and the number of attempts made by the bull before completed ejaculation. A study was also made of the effect of different frequencies of semen collection on the semen production of these bulls. These data will also be reported.

APPROACHING THE PROBLEM OF FULL-FEEDING WHEAT TO BEEF CATTLE THROUGH GRAIN ROUGHAGE MIXTURES. Bruce R. Taylor and W. L. Blizzard, *Oklahoma Agricultural Experiment Station, Stillwater.*

The feeding of coarsely ground wheat mixed with either silage or cottonseed hulls proved to be an easy, safe, and satisfactory way to substitute wheat for corn in a calf fattening ration for beef calves. When mixed with silage, its value proved to be 107 per cent that of corn per pound whether used as a complete or partial substitute for corn. Silage proved superior to cottonseed hulls as a roughage with which to mix wheat. Ground wheat mixed with hulls had only 102 per cent the gain producing value of corn and the selling price and carcass grades of the cattle were lower than other lots of the series fed either corn or wheat mixed with silage.

Beef calves consumed 7 per cent less coarsely ground wheat than ground shelled corn daily, but gained at an equal rate, sold at the same price, and produced dressed yields and identical grading carcasses.

Dairy Cattle Section

C. B. Bender, *Chairman*

RENTAL RATE PLAN FOR BULLS USED IN ARTIFICIAL INSEMINATION. J. W. Bartlett and E. J. Perry, *Agricultural Experiment Station, New Brunswick, N. J.*

Since the organization of the first cooperative artificial breeding unit in New Jersey in May 1938, there has been much controversy relative to a satisfactory plan of leasing bulls for service in artificial insemination programs in the State. On June 1, 1943 the Association accepted a rental plan submitted by the authors, which was based upon performance for proved bulls and performance pedigree for unproved bulls. All charges are on the basis of

each satisfactory sample of semen accepted from a bull. The base charge for proved bulls having 5 or more tested daughters is $3.00 per semen sample. In addition 10 cents per point is allowed for each percentile his daughters average yearly fat record is above the breed average in total fat for age and class. If a bull has less than 5 milking daughters the rate of compensation is 8, 6, 4 or 2 cents per point above breed average in a descending scale from five to one tested daughter. The method of compensation for unproved bulls allows a base rate of 50 cents per satisfactory semen sample for a yearling bull with a 25 cent annual increase to $1.50 at 5 years of age.

THE USE OF DRIED WHEY AND BLOOD MEAL IN THE RAISING OF CALVES ON LIMITED AMOUNTS OF MILK. I. L. Hathaway, G. W. Trimberger, and H. P. Davis, *Dairy Husbandry Department, University of Nebraska.*

Fifty grade Holstein calves were successfully reared from approximately three weeks to six months of age on U. S. No. 1 grade alfalfa hay a grain mixture, a vitamin A and D concentrate and various quantities of skim milk, supplemented with a mixture composed of three and two-tenths parts of dried whey to one part of blood meal. Six and eight-tenths pounds of this mixture were used to replace fifty pounds of skim milk. The calves in five of the lots made an average daily gain of approximately one and one-half pounds per head for twenty-one weeks. There was no statistically significant difference between the average gains in weight made by five of the six lots of calves. From the data obtained in this study it was concluded that under the conditions of this experiment: Six and eight-tenths pounds of a mixture composed of 3.2 parts of dried whey and one part of blood meal, is a satisfactory substitute for fifty pounds of skim milk in feeding healthy dairy calves approximately three weeks of age and weighing not less than 104 pounds. Healthy, vigorous dairy calves can be raised from three weeks to six months on fifty pounds of skim milk if properly supplemented with dried whey, blood meal, alfalfa hay, a grain mixture and a vitamin concentrate.

LONG DISTANCE SHIPPING OF DAIRY BULL SEMEN. H. A. Herman, E. J. Perry and E. W. Swanson, *University of Missouri Agricultural Experiment Station, Journal Series No. 917.*

Statewide shipping of dairy bull semen for use in artificial insemination is being regularly practiced. Long distance shipping of semen has not progressed so satisfactorily. Shipment by ordinary means requires 48 hours or longer and the maintenance of temperatures between 35 and 45° F., highly essential to preservation of semen, has been difficult to control. In view of the desirability of making matings of outstanding animals although located many miles apart and in consideration of the possibilities of continent to continent shipments as part of the postwar restoration program of livestock in the war devastated countries, the problem of long distance semen shipment has been further investigated by the Missouri and the New Jersey Agricultural Colleges. A study of method of packaging has resulted in desirable storage temperatures being maintained for more than 80 hours with atmospheric temperatures between 80 and 90° F. Twenty-four semen shipments have been made and the semen has reached its destination in a condition comparable to storage the same length of time in a refrigerator at 40° F. Twelve cows have been inseminated and eight conceptions have resulted. The semen used was in transit from 48 to 130 hours and ranged from 70 to 90 per cent motility when packed. Six inseminations from semen stored over 144 hours have not been successful. Additional semen shipments from Missouri to New Jersey to be used in artificial breeding associations are being made at regular intervals and this data will be summarized and reported at a later date.

THE NUTRITIVE VALUE OF CORN MEAL PRESERVED SILAGES. W. A. King and C. B. Bender, *New Jersey Agricultural Experiment Station.*

Second-cutting alfalfa in ½ bloom stage and soybeans with pods partly filled were ensiled with 480 and 250 pounds of corn meal respectively per ton of green material. The silages were

well-preserved, containing no evidence of butyric acid. Two groups of five cows each were fed 50 pounds of these silages with a mixed hay ad libitum (approximately 11 pounds). Under this feeding regime the average cow did not maintain the initial milk production of 40 pounds daily, dropping rapidly to 30 pounds and less. Those cows receiving the corn meal soybean silage showed an average loss of 58 pounds of live weight, whereas those fed the alfalfa silage maintained their weight. These drops in production and losses of weight were primarily due to the inability of the average cow to consume sufficient nutrients with this diet. Two cows, however, with the ability to consume large quantities of the corn meal alfalfa silage were maintained very satisfactorily in both milk production and live weight. Thus the limiting factor in this experiment was the roughage capacity of the cows. In order to feed good producing cows all of their concentrates through silage it would be necessary to add more than 500 pounds of corn meal per ton of green material. A loss of about 10 per cent of the digestible nutrients of the corn meal in addition to normal silage fermentation losses was observed both in the chemical analysis and in the results of the feeding trials.

THRESHED PEANUT HAY FOR DAIRY COWS. A. H. Kuhlman and H. W. Cave, *Oklahoma A. & M. College.*

Peanuts have become an essential war crop in the cotton belt. Oklahoma farmers in 1942 harvested 265,000 acres of peanuts, an area almost equivalent to the total acreage devoted to this crop in the state during the preceding five years. Estimates for 1943 indicate the production of 530,000 acres of peanuts in Oklahoma and more than a million acres in Texas. Other southern states also show great increases in peanut production. While the peanut crop is grown primarily for the nuts, the vines are an important by-product because they can be used as a substitute for other legume roughages. Threshed peanut hay is extremely variable in quality due to differences in the care and methods used in harvesting, curing and threshing the crop. Its feeding value depends on the color of the hay, the proportion of leaves retained and the amount of dirt or dust present. The results of the first of a series of feeding trials conducted at this station indicate that high quality, bright-colored, leafy, threshed peanut hay is equal to good alfalfa hay when fed to milk cows. This hay contained 90.1 per cent dry matter, 11.0 per cent protein, 2.6 per cent fat, 21.5 per cent fiber, 7.6 per cent ash and 47.4 per cent nitrogen-free extract. Peanut hay, if carefully conserved, will yield from one-half to one ton of good roughage per acre in many fields. Maximum use should be made of it by southern farmers during the present shortage of roughages and high protein concentrates.

EFFECT OF COLOSTRUM ON THE VITAMIN A AND CAROTENE CONTENT OF BLOOD PLASMA OF NEWBORN CALVES. L. A. Moore and M. H. Berry, *Department of Dairy Husbandry, University of Maryland.*

Blood samples were drawn from calves of the Holstein, Ayrshire, Guernsey, and Jersey breeds soon after birth and before they nursed the cow, and for seven days thereafter. Plasma vitamin A and carotene determinations were made on all samples. The calves were removed from the cow at the end of the third day. The vitamin A content of plasma at birth was low but at the end of 24 hours usually showed about a five-fold increase. Maximal values were reached at about three days of age after which there was a gradual decline. Carotene values followed much the same pattern. There were no marked differences between breeds in the vitamin A content of the blood plasma; however, the carotene content of the blood plasma of the Jersey and Guernsey breeds was three to four times higher than for the Holstein breed. There was considerable individual variation in the plasma vitamin A and carotene content. In a few cases neither the plasma vitamin A or carotene values showed an increase even though the calves apparently consumed the colostrum. Usually these calves died from infection. In three cases in which the colostrum was withheld and whole milk was fed, the plasma vitamin A and carotene content showed very little increase. Two of the three calves died of infection. The plasma vitamin A and carotene values did not reach a maximum where the calf was left with the cow for 12 hours but were almost maximal when left for 24 hours.

Horse and Mule Section

L. H. Blakeslee, *Chairman*

SOME ASPECTS OF FERTILITY IN HORSES RAISED UNDER WESTERN CONDITIONS. S. R. Speelman and W. M. Dawson, *United States Department of Agriculture.*

Data are presented on certain aspects of fertility of 209 mares bred to 14 stallions over a 15-year period at the U. S. Range Livestock Experiment Station, Miles City, Montana, in a cooperative study with the Montana Agricultural Experiment Station. The general fertility level was 59.6 per cent (based on the number of mares bred) and 46.8 per cent (based on the number of estrus periods in which the mares were bred). The year in which the mare was bred, age of mare, breed of mare, and the stallion to which she was mated all significantly affected the fertility level. The effect of year was apparently not connected with any trend but there were slight indications that it was associated with the fertility of the particular stallions used in different years. Very young mares as well as old mares appeared to have a lower fertility than mares of intermediate ages. The order of fertility of the mares of the different breed groups was Belgian, Morgan, grade-light and grade-draft. Differences in the stallions used and possibly management appeared to account for much of the difference. Significant differences were found between the fertility of stallions bred to the same mares in seven out of 15 comparisons. One set of twins was obtained in 567 foalings. The sex ratio was 97.6 males per 100 females for all the foals (568). Eighty-seven and two-tenths per cent of the foals were weaned. The number dying of different causes are listed.

Meats Section

R. S. Glasscock, *Chairman*

THE RIBOFLAVIN CONTENT OF BEEF AND PORK MUSCLES. D. E. Brady, W. J. Peterson, A. O. Shaw, *North Carolina Agricultural Experiment Station, Raleigh.*

Determinations were made of the riboflavin content of 20 muscles from 4 wholesale cuts of 12 yearling beef carcasses. Values ranged from 1.2 to 2.3 gamma per gram of fresh lean tissue. Muscles analyzed were the following: latissimus dorsi; rhomboideus thoracalis; trapezius thoracalis; triceps, lateral head; triceps, long head; biceps brachii; coraco-brachiolis; posterior deep pectoral; deltoideus; serratus thoracis; vastus intermedius; sartorius; biceps femoris; semitendenosus; semimembranosus; longissimus dorsi; psoas major; serratus dorsalis; longissimus costarum; transversus abdominis. Average values for the riboflavin content of the tongue, spleen, liver and heart were 3.1, 3.9, 27.2, and 10.7 gamma per gram of fresh tissue respectively. The averaged values of the muscles from the wholesale cuts; prime rib, chuck, round, and short loin were remarkably similar being 1.7, 1.8, 1.6, and 1.8 gamma per gram respectively. No relationship was found between average daily gain, riboflavin intake per cwt. of gain or carcass finish when compared with the riboflavin content of the muscles. Length of feeding period, however, appears to show a direct relationship. Riboflavin determinations on the longissimus dorsi and psoas major muscles of pork loins showed average values of 1.2 and 2.8 gammas per gram of fresh muscle respectively and values of 1.4 and 2.9 on the cooked basis. Losses incurred in roasting to an internal temperature of 85° C. are small.

COMPOSITION AND NUTRITIVE VALUE OF THE DRESSED CARCASSES AND CUTS OF INTERMEDIATE TYPE HOGS AS RELATED TO LIVE WEIGHTS OF THE ANIMALS. O. G. Hankins and N. R. Ellis, *United States Department of Agriculture.*

Consumers are always concerned about the size of the cuts of meat available in the retail market. This is especially true under existing conditions of limited supply and controlled distribution. There is also a vital interest in the proportions of fat, lean, total edible meat,

and bone and, perhaps less consciously but just as definitely, in the nutritive value of the cuts consumed. During a period of several years, data bearing on this problem were obtained from a total of 64 hogs of intermediate type. The hogs ranged from 167 to 254 pounds in live weight and the feeding was representative of that employed in finishing market hogs in the United States. Estimations were made of the weights of the dressed carcasses and cut, as well as the edible meat thereof, for hogs of significant market weights. They were supplemented with estimates of fat, lean, bone and skin content and of chemical composition of the edible portion of the meat. Values were also obtained for the caloric value per pound of the carcasses and cuts and for that value, as well as the amount of protein, per pound of edible meat. The study brings out striking and important relations between weight of animal, carcass or cut and the other factors mentioned.

NATIONAL LIVE STOCK AND MEAT BOARD RESEARCH PROGRAM. R. C. Pollock, Chicago, Illinois.

Appreciating that the importance of a food depends upon the nutrients it supplies for the maintenance of health, the Board inaugurated a nutritional research program on meat nineteen years ago. Through this research, the Board has made a great contribution to the science of nutrition in addition to finding many facts of great value to the industry. The Board's program has been expanded from year to year. Twenty-nine studies have been supported. Some have been completed in one year while others have taken many years. One study, still in progress, has been supported for thirteen years. At the present time, nine studies are being conducted at six of our leading universities. This extensive research program has included the following: the biological value of the proteins of meat; the amino acid content of meat proteins; meat as a source of the vitamin B complex; meat as a source of iron; meat in the prevention and treatment of anemia; meat in the prevention of low phosphorus rickets; fat metabolism and essential unsaturated fatty acids; relation of the essential unsaturated fatty acids to the health of the skin; retention of B vitamins during the cooking of meat; effect of high protein diet on the kidneys; meat in relation to weight control; meant in relation to regeneration of blood plasma protein; vitamin M and nutritional cytopenia.

MEAT PROTEIN AND HEMOGLOBIN FORMATION IN HUMAN SUBJECTS. Ruth M. Leverton, *University of Nebraska.*

The importance of protein in hemoglobin formation and the treatment of simple nutritional anemia in human subjects has been studied at the University of Nebraska, Department of Home Economics. College women have been used as subjects and the method has been to add dietary supplements to their customary self-chosen diets and follow hemoglobin changes over a period of six to twelve weeks. In one series eighteen girls were given a five ounce serving of meat every day and the findings compared with those of eighteen girls who received only three ounces of meat a day. The larger quantity of meat resulted in a small but consistent rise in the hemoglobin content of the blood. In another series the protein supplement was from food sources other than meat. Twelve girls living on a lacto-ova vegetarian diet and twenty-five girls on an ordinary diet containing meat were given an additional twenty grams of protein daily from legumes, milk products, and eggs. The hemoglobin values of these subjects did not change significantly.

Nutrition Section

J. K. Loosli, *Chairman*

THE TOLERANCE OF LAMBS TO VARYING LEVELS OF BLACKSTRAP MOLASSES. H. M. Briggs and V. G. Heller, *Oklahoma Experiment Station.*

Eight Rambouillet wether lambs have been used to determine the level which blackstrap molasses must be fed before digestion efficiency is impaired. Each lamb was fed each of four experimental rations in two digestion trials, or a total of sixteen digestion coefficients were secured for each ration. The basal ration consisted of 410 gms. shelled yellow corn, 44 gms.

cottonseed cake, and 454 gms. ground alfalfa hay. In the remaining three rations corn was replaced by 5, 10, and 15 per cent blackstrap molasses. Levels of from 20 to 25 per cent molasses in the ration previously indicated that the apparent digestion coefficients of protein, fat, and nitrogen-free-extract were lowered an appreciable amount while a 10 per cent level of molasses had only little effect. In this study the apparent protein digestion coefficients for the four rations were not greatly different except there was a tendency for slightly lower protein digestion when the lambs were fed 15 per cent molasses. The apparent fat digestion coefficients of the basal ration and the 5, 10, and 15 per cent molasses rations were 66.8 per cent, 65.9 per cent, 64.4 per cent, and 60.9 per cent respectively. These results confirm those of previous studies that lambs cannot efficiently digest the ether extract of the ration when fed high sugar levels. Levels of molasses varying from 5 to 15 per cent showed no consistent alteration of the apparent digestion coefficients of fiber and nitrogen-free-extract.

FURTHER STUDIES ON BLOAT IN CATTLE. H. H. Cole, S. W. Mead and W. M. Regan, *California Agricultural Experiment Station.*

New means of inducing bloat have been studied. Twelve cases of bloat were induced by feeding green alfalfa tops in the barn to 4–6 cows for 9 days. Seven of these bloat cases were sufficiently severe to require treatment. In studies in which it is essential to follow feed consumption or in which the rate of gas formation is to be determined, the feeding of tops has definite advantages over pasturing. Twenty-one mild cases of bloat were produced in 4 cows over a 15 day period by feeding a ration consisting of 60 per cent finely ground alfalfa hay and 40 per cent concentrates while only one case of bloat was encountered over a similar period with whole alfalfa hay and concentrates. This experiment gives convincing proof that the physical character of the feed is an important etiological factor in bloat. Studies on prevention of bloat are being continued and the results, still incomplete, will be reported.

FURTHER STUDIES ON THE EFFECT OF DIET ON BROOD SOW PERFORMANCE. T. J. Cunha, O. B. Ross, P. H. Phillips, and G. Bohstedt, *University of Wisconsin and Commercial Solvents Corporation.*

More data have been secured on the problem of using simplified rations for brood sows. Sows fed a basal ration of ground yellow corn 80.5 per cent, soybean oil meal 13.0 per cent, ground alfalfa hay 5 per cent, bone meal .5 per cent, limestone .5 per cent, iodized salt .5 per cent plus supplementation with irradiated yeast and shark liver oil failed to reproduce normally. Three out of four sows were sterile and the fourth gave birth to a poor litter. Increasing the alfalfa content to 15 per cent resulted in normal reproduction. The addition of 1 per cent B-Y riboflavin supplement, a good source of most B-complex vitamins, was ineffective in supplementing the basal ration. The addition of 2 per cent of the B-Y riboflavin supplement improved the growth response of animals fed the basal ration, but it failed to bring about completely normal performance. Some abnormal pigs were obtained at birth when either level of B-Y riboflavin supplement was fed. The addition of crystalline riboflavin to the basal ration was found to be detrimental. Sows fed this ration gave birth to a number of abnormal pigs and 75 per cent of all pigs died before weaning. Likewise, the supplementation with choline did not improve the performance of sows over those fed the basal ration only. Approximately 95 per cent of these pigs were abnormal at birth and all pigs succumbed within a week. Normal reproduction was obtained with the sows fed soybean lecithin plus pyridoxine. The deficiencies of the basal ration under dry-lot conditions involve fertility, reproduction, and lactation. Parallel experiments with rats substantiate the swine work. Experiments with the rat have shown that inositol, choline, and pyridoxine in combination with some unknown factor or factors present in liver adequately supplement this basal ration.

PANTOTHENIC ACID AND PYRIDOXINE AS FACTORS IN THE OCCURRENCE OF LOCOMOTOR INCOORDINATION IN SWINE. N. R. Ellis, L. L. Madsen, and C. O. Miller, *United States Department of Agriculture.*

Experiments are described on the value of pantothenic acid and pyridoxine when added to swine diets in preventing the development of locomotor incoordination resulting from nerve

degeneration. In an earlier paper, findings were reported on growing swine fed a normal diet given a dry-heat treatment with and without the addition of supplements of various feedstuffs. It has been found that calcium pantothenate, added to the heated diet, greatly reduces the incidence and severity of the disorder but the further addition of pyridoxine appears to be necessary for full prevention. These findings were also confirmed by the use of a diet of purified food constituents supplemented with the known vitamins required by swine. In addition to pantothenic acid and pyridoxine, there was evidence that choline was also necessary for protection on the purified diet. The rather frequent occurrence of locomotor incoordination in growing swine fed on normal diets of corn with supplements appears to be due to the borderline level of pantothenic acid present in relation to the requirements.

ASSOCIATIVE EFFECTS OF PROTEIN, CARBOHYDRATE AND FAT. E. B. Forbes and R. W. Swift, *Institute of Animal Nutrition, The Pennsylvania State College.*

Experiments were conducted with 7 groups of 12 mature albino rats to demonstrate the efficiency of utilization of the energy of beef muscle protein, cerelose and lard, fed separately and variously combined, as supplements to a complete, basal maintenance diet. Separately determined dynamic effects of beef protein, cerelose and lard decreased in the order in which these nutrients are named. Mixed supplements containing beef protein increased the heat production at the expense of protein; and supplements containing cerelose increase the heat production at the expense of carbohydrate; but any mixed supplement, whether containing lard or not, decreased the production of heat at the expense of fat. The most efficiently utilized supplement was that composed of beef protein and fat; and the least efficiently utilized was that composed of beef protein and cerelose. The ratio of the direct to the computed value of the mixture of cerelose and beef protein was as 87.5 to 100; of cerelose, beef protein and lard as 78.3 to 100; of cerelose and lard as 65 to 100, and of beef protein and lard as 46.3 to 100. There is, therefore, no one value for the dynamic effect of protein, of carbohydrate, or of fat. The most significant dynamic effects of these nutrients would be the separately undeterminable values represented in complete and perfect diets.

IODINE-FLUORINE RELATIONSHIPS IN SHEEP NUTRITION. J. D. Hatfield, C. L. Shrewsbury, F. N. Andrews, and L. P. Doyle, *Purdue University.*

Fattening lambs were fed various levels of fluorine from rock phosphate in conjunction with rations containing adequate and inadequate iodine. The growth of the lambs was adversely affected by the higher levels of fluorine (6.0 milligrams per kilogram of body weight) and to some extent by smaller amounts and was not related to the iodine content of the ration. Lambs fed rations that were not supplement with iodine had thyroid glands of abnormal histological structure and low iodine content while glands from lambs receiving iodine were normal in these respects. Fluorine in the ration increased the percentage of iodine in the thyroid gland but had a variable effect on the total iodine storage.

THE QUANTITATIVE CALCIUM REQUIREMENTS OF GROWING FOX PUPS. Lorin E. Harris, Charles F. Bassett, Sedgwick E. Smith, and Elden D. Yeoman, *Fish and Wildlife Service, U. S. Fur Animal Experiment Station and Cornell University.*

To determine the calcium requirements of fox pups for normal growth and fur development, 90 silver fox pups were divided into five groups of 18 animals each. They were fed, respectively, diets containing 0.16, 0.20, 0.30, 0.41 and 0.51 per cent calcium (dry basis). All diets contained 0.52 per cent of phosphorus and included 1.29 per cent cod liver oil (dry basis) containing 400 chick units of vitamin D per gm. Lameness was first observed in 7 days; shock occurred in three groups in 13 to 27 days; the leg bones soon became extremely crooked in four groups; swelling of the muzzle and enlargement of the cranial bones developed in 14 of the animals receiving 0.16 per cent and 1 animal receiving 0.20 per cent calcium. The severity of the deficiency symptoms was proportional to the amounts of calcium fed. Animals fed the 0.20 per cent level, when given increased amounts of calcium (0.91 per cent) from mid-experi-

ment on, showed quick improvement from lameness, but the leg bones remained crooked. Animals receiving 0.51 per cent calcium were normal at end of experiment. The food consumption and gain in liveweight was directly proportional to the amount of calcium fed. The bone volume, specific gravity, and per cent ash in the fat free bone, indicate the requirement to be between the 0.3 and 0.4 per cent level of calcium; however, observations of deficiency symptoms during the experiment indicate that the level of calcium required for normal bone development throughout the growth period lies between 0.4 and 0.5 per cent calcium. A deficiency of calcium indirectly causes small pelts through lack of growth and some rubbing of the pelt due to the crippled condition of the animals.

CORRELATION RELATIONSHIPS BETWEEN RATE AND EFFICIENCY OF GAIN. Bradford Knapp, Jr., and A. L. Baker, *U. S. Range Livestock Experiment Station.*

The animal husbandman has assumed that there is always a high correlation between rate and efficiency of gain. This may or may not be true according to the conditions of the experiment. It is the purpose of this paper to show an exception to this close relationship and to show that gross efficiency may be misleading under certain conditions. The literature contains correlations from 0.34 (Winters 1933) to 0.88 (Black and Knapp 1936) between rate and efficiency of gain. In a recently completed study, 66 steers were individually fed for a 273 day feeding period. The correlation between rate and efficiency was 0.49. There were large variations in initial and final weights and gains in the feed lot. Correction of efficiencies by the method of analysis proposed by Titus et al. (1934) resulted in materially increasing the correlation between rate of gain and corrected efficiency of gain. In record of performance studies, it is advantageous at times to feed for a standard length of feeding period. In experiments of this type, comparisons of gross efficiency are misleading and are likely to lead to selection of lighter, poorer gaining steers. It is concluded comparisons of efficiencies can be made only between animals of the same size and that in a time constant population where animals are not the same size, selections should be made on rate of gain rather than on observed gross efficiency.

VEGETABLE VERSUS ANIMAL PROTEIN SUPPLEMENTS FOR YOUNG PIGS. J. L. Krider, B. W. Fairbanks, Damon Catron and W. E. Carroll, *Illinois Agricultural Experiment Station.*

Observations were made on three series of tests with growing-fattening pigs fed as follows: (1) Pigs from birth to 75 pounds fed, in drylot, a protein supplement containing animal proteins, (2) Pigs from birth to 75 pounds fed, in drylot, a protein supplement containing only vegetable proteins, and (3) Pigs on rye pasture during lactation, transferred to the drylot at weaning and fed in drylot a protein supplement containing only vegetable proteins. Plant protein supplements gave satisfactory results when fed in drylot to pigs that had access to rye pasture before weaning. Plant protein supplements fed to pigs confined to the drylot continuously from farrowing gave unsatisfactory results. Rations of pigs fed in drylot from birth were improved by inclusion of animal proteins. Two basal rations were used for the two series of growing-fattening pigs confined to drylot from birth, (1) Animal Proteins—ground yellow corn, wheat flour middlings, tankage, fish meal, soybean meal, fortified cod-liver oil, and minerals; (2) Plant Proteins—ground yellow corn, wheat flour middlings, soybean meal, fortified cod-liver oil and minerals. These basal rations were fortified with either (1) Synthetic thiamin, riboflavin, nicotinic acid, pantothenic acid, pyridoxine and choline, or (2) Six per cent dried corn distillers' solubles, or (3) 10 per cent alfalfa meal. None of the fortifications gave adequate nutrition to pigs fed only vegetable proteins in drylot. The basal ration containing fish meal and tankage was inadequate. The addition of synthetic vitamins to this basal ration induced the most rapid growth.

ATTEMPTS TO FIND WAR-TIME FEEDS IN GERMANY. Burch H. Schneider, *West Virginia University.*

In an extensive study of feedstuffs, the author has noticed in the German literature a number of attempts to make use of unusual materials for livestock feeding. Some of these are

not new, as they were the objects of many experiments published during and after World War I. These attempts were continued prior to the present conflict. Some of the materials considered are as follows: sawdust and various straws treated with sodium hydroxide, calcium hydroxide, sodium sulfide, or hydrochloric acid of different strengths for different periods, with and without pressure, wood sugar, wood sugar yeast, wood cellulose, cellulose manufacturing residue, tree leaves, heather, lichins, silt, peat, potato byproducts, potato tops, other byproducts high in fiber, urea and amid mixtures, corn meal, ossein, rumen contents of slaughtered animals. Chemical treatment of sawdust and of straws undoubtedly can increase their digestibility, but these feeds when included in rations almost invariably depress the digestibility of one or more nutrients. These unusual materials probably are not of practical importance as feeds in peacetime production and trade, although no one can predict that none of them will ever find a place in normal economy. By far the greatest progress in recent years toward meeting the feeding emergency in Germany as in other countries has been made in the use of better quality roughages from immature legumes, grasses and other crops, fed fresh, and dried and ensiled by various methods.

Pasture and Range Section

R. H. Lush, *Chairman*

PASTURE AS A FEED FOR HOGS. G. Bohstedt, *University of Wisconsin.*

Pasture for hogs is economical and practical under almost any circumstances but especially under a wartime emergency, if for no other purpose than the saving of critical grains or concentrates. Good pasture saves from 10 to 20 per cent of the grain that would be needed for efficient production of pork in drylot feeding. This saving is brought about by several favorable factors inherent in pasture, some of these being the carbohydrate and high-quality protein of growing forage. Definite supplementary effects to ordinary grain rations, especially those balanced entirely from plant sources, are a number of easily assimilated minerals, carotene, a number of the B-complex vitamins, and other vitamins that are found in relative abundance in green growing vegetation. Vitamin D is supplied automatically by exposure of the animals on pasture to direct sunshine. Other health factors are exercise and, with reasonable care, sanitation. Rating some of the prevalent hog pastures in and around the Corn Belt, those classed as "excellent" are alfalfa and red clover, which may be grown in combination with grasses, and Dwarf Essex rape which may be grown with oats or other cereals, and which may also include Canadian field peas. "Good" during relatively short seasons of growth are Sudan grass, soybeans, oats-and-peas, rye, and during spring and fall, bluegrass. "Fair to poor" may be classed midsummer bluegrass, other drought-susceptible grasses, and sweet clover. The quality and efficiency of each of these pastures is largely determined by conditions of weather, soil, and its fertility.

GOVERNMENT PASTURE PROGRAMS. C. R. Enlow, C. E. Carter and C. D. Lowe, *War Food Administration.*

The improvement of grassland is an important part of the government's entire conservation program. Farmers and ranchmen are given assistance in the form of technical help, materials such as lime, phosphate, and seed, and payments to offset out-of-pocket costs in order to provide ample feed for livestock. Pastures, in order to be highly productive, must be on good land and on many farms are included in the crop rotation. A tremendous increase in improved pastures on irrigated lands has come about because the income is equal to or above that from other farm crops. Bringing pastures definitely into crop rotation helps tremendously in keeping the yields of other crops at a high level. Permanent pastures also are being established on idle lands, such as weedy, brushy areas along streams, poorly drained areas, and lands subject to over-flow. Temporary and supplemental pastures also occupy a large place in the government's program. In the South, there are opportunities for year-round pasture where farmers can seed clover-grass pastures for fall and winter grazing, lespedeza-grass

pastures for summer grazing and kudzu for later summer and early fall grazing. On the range lands of the West, the objectives of the government are to so handle the grazing of livestock as to produce the maximum amount of forage, consistent with conservation of soil and moisture.

PASTURE AS A FEED FOR DAIRY CATTLE. C. F. Huffman, *Michigan State College.*

The only practical way of harvesting most legumes and grasses at the peak of their nutritive power is by using them for pasture. Pasture herbage in the young stage of development is rich in the dietary principals required for growth, reproduction, and lactation. Occasionally, however, it may be deficient in some dietary essentials. Pasture experiments with lactating cows should be conducted without supplemental grain feeding, unless that is the problem under investigation. Both pasture grass and grain contain unknown lactation stimulating factors, consequently grain feeding makes it impossible to test the pasture for milk producing power. The best cows to use in pasture studies are those which have been fed legume hay alone for at least three months prior to their use in pasture studies. This system depletes the cow of the unknown factors which may have been stored in the animal. Loss of body weight by cows on pasture, associated with sustained milk production, is a good indication that the pasture contains the unknown milk stimulating factors so desirable in pasture. Gain in weight by good cows on abundant pasture frequently is an indication of a deficiency in the herbage. A pasture which gives desirable results with beef cattle may be inferior for lactating cows. The evaluation of pastures on the T. D. N. basis from the standpoint of milk production is frequently inaccurate. The body weight maintained and the 4 per cent fat corrected milk produced per acre give the productive power of pasture.

Sheep and Wool Section

W. G. Kammlade, *Chairman*

THE EFFECT OF SOME FACTORS ON THE BLOOD PHOSPHORUS LEVEL OF RANGE EWES. W. M. Beeson, Clair E. Terrill, and D. W. Bolin, *Idaho Agricultural Experiment Station and United States Department of Agriculture.*

Data are presented from a four-year study on the seasonal variation in the blood phosphorus level of range ewes. Blood samples were collected from a group of about 40 Columbia ewes at 3 to 7 different times during the year. Seasonal trends in blood phosphorus level were fairly definite and variations between seasons were highly significant. Highest blood phosphorus levels were found on the winter and spring ranges, while lowest levels were found at lambing time, in the late summer and fall, and on the winter feed lot. Supplemental feeding of cottonseed cake or oats on the winter range or feed lot increased the phosphorus content of the blood. Blood phosphorus was lower for ewes that had lambed than for ewes that had not yet lambed. Dry ewes had higher blood phosphorus than ewes which were pregnant or suckling lambs. Ewes with one lamb had higher blood phosphorus than ewes with two lambs. A relationship was found between gain or loss in body weight and blood phosphorus. Ewes which were losing weight tended to have higher blood phosphorus. Blood phosphorus tended to decrease with age. No definite evidence of phosphorus deficiency was found excepting for low blood phosphorus levels. The percentage of ewes having blood phosphorus values of 3.5 mg. or below for the various seasons were 5.3 for the fall range, 2.5 for the feed lot, 20.0 at lambing, 2.7 for the spring range and 10.0 for the summer range.

METHODS OF FATTENING LATE NATIVE LAMBS. W. P. Garrigus, *University of Kentucky.*

The fattening of Kentucky lambs dropped too late to finish for the May, June, or early July markets presents a difficult problem due to parasitism, droughty pastures, and heat. Three years' results at this Station show that shearing such lambs in early July increased their rate of gain by from 22.4 to 55.6 per cent. The sheared lambs yielded over two pounds

of wool, dressed nearly two per cent higher than the unsheared lambs and were graded nearly one full grade higher at marketing time. Lambs taken off permanent bluegrass pasture on July 22, 1942, and fed in drylot for 112 days had no nodules on their intestines at time of slaughter. Many nodules were found on the intestines of a similar lot of lambs that remained on this bluegrass field for the 112-day period. Phenothiazine administered in 15-gram doses on August 21, September 18, and October 16 produced no significant reduction in nodule formation nor increase in rate of gain or market finish. For the first 70 days (July 24 to October 2) lambs on lespedeza pasture only outgained those full fed U. S. No. 2 yellow shelled corn and U. S. No. 2 second cutting alfalfa hay in drylot. During the remaining 42 days the drylot-fed lambs maintained their rate of gain, whereas those on the lespedeza lost weight. Late and light seed formation may have accounted for the poor showing of the late lespedeza pasturage.

A PRELIMINARY REPORT ON THE POST-NATAL DEVELOPMENT OF THE FIBER CHARACTERISTICS OF NAVAJO SHEEP. James O. Grandstaff and Cecil T. Blunn, *U. S. Department of Agriculture, Ft. Wingate, New Mexico.*

The primary purpose of this study was to determine the optimum age for evaluating fleece quality as a guide to selection and culling of the sheep for wool improvement. Fifteen Navajo ewe lambs were sampled from side, thigh, and back positions at 13 ages ranging from 28 to 364 days. The samples were analyzed for percentages of wool, hair, and kemp fibers, and the diameter-distribution of each type of fiber was measured. Samples at 28 days contained an average of 60 per cent wool, 24 per cent hair, and 15 per cent kemp fibers by number. During the next 56 days wool fibers increased 21 per cent, while hair and kemp fibers decreased 9.5 and 10.5 per cent, respectively. From 84 to 364 days of age proportions of the three types of fibers remained relatively constant. Side, thigh, and back samples followed the same trend. Differences between lambs were greatest at 28 days of age, but decreased rapidly during the first 56 days and to a limited extent thereafter. Highly significant differences were found between sheep, positions, and ages, the latter being due to sharp changes in fiber content of fleeces during early months of growth. The diameter-distributions of woof and hair fibers did not change significantly during the year, but kemp showed a significant change between the 28 and 56 day samples. Results indicate that lambs can be selected for fleece quality at 84 days of age, but further work is required to determine the significance of differences observed at earlier ages.

CLEAN-WOOL YIELDS IN SMALL SAMPLES FROM EIGHT BODY REGIONS AS RELATED TO WHOLE-FLEECE YIELDS IN FOUR BREEDS OF SHEEP. Elroy M. Pohle and L. N. Hazel, *United States Department of Agriculture, Dubois, Idaho.*

Clean wool yields of small samples from 8 body regions were compared with the clean wool yields of the whole fleeces to determine the most accurate regions for sampling a fleece. From 15 yearling ewes for each of the Rambouillet, Targhee, Corriedale and Columbia breeds, 480 small samples and 60 whole fleeces were used. Average bone-dry clean wool yields for all four breeds were highest from the shoulder, hip, thigh and belly and lowest yields were found on withers, back, rump, and side. The average yield for all the sheep was 38.6 per cent. The difference of 3.4 per cent between average small-sample and whole-fleece yield was highly significant. Breed differences were highly significant for whole-fleece and small-sample yields. Differences among sheep within each breed were also highly significant. The *a* and *b* coefficients (with small-sample yield as the dependent variable) were similar for the four breeds but not for the eight regions. Thus the most accurate coefficients for predicting whole-fleece yields seem to be the *a* and *b* values for a particular region averaged for the four breeds. The correlation involving the withers, back, and rump are lower than the others, as were the corresponding regressions and are the less desirable regions for taking small samples. Differences in accuracy among the other five regions were so small that choice for use falls to whichever is easiest to sample.

SAMPLING AND MEASURING METHODS FOR DETERMINING FINENESS AND UNIFORMITY IN WOOL. Elroy M. Pohle, L. N. Hazel and H. R. Keller, *United States Department of Agriculture, Dubois, Idaho.*

Wool samples from six body regions on each of 10 Rambouillet yearling ewes were examined by the cross-section method to compare the accuracy of (1) sampling methods and (2) methods of measuring mean diameter and uniformity. The variation in fiber diameter associated with sheep, body regions, levels along the fiber, and the various interactions were estimated quantitatively, all being statistically significant. Standard errors calculated from theoretical formulas indicated that samples of completely randomized fibers would be more efficient for estimating average diameter in both number of cross-sections prepared and fibers measured than samples from controlled body regions or levels along the fiber. The ability to obtain completely randomized samples of wool fibers from individual fleeces appeared to require the opening and mixing of the whole fleece; hence a modified method of blending fibers from definite body regions, suitable for the usual wool laboratory, was investigated. Two trials indicated that the sampling conditions required for the modified method could be fulfilled by hand carding small locks (equal size) from different body regions. The accuracy of single estimates of fineness by the count and the rapid comparator methods was equivalent to that of measuring approximately 75 and 62 fibers respectively. Both are much faster to apply than measuring an equivalent number of fibers. Both short-cut methods were sufficiently accurate to distinguish between uniform and variable fleeces.

COMPARISON OF GROWTH IN KARAKUL AND MUTTON BREEDS OF SHEEP. Victor L. Simmons, *United States Department of Agriculture, Beltsville, Maryland.*

Body weights of 92 purebred Karakul, 37 Karakul×Blackfaced Highland, and 30 Karakul×Corriedale lambs were compared with the body weights of 86 Hampshire, 76 Shropshire, 98 Southdown, and 74 Corriedale lambs to determine their relative rates of growth from birth to 13, 26, and 52 weeks of age when raised under farm conditions. However, of the numbers of lambs at birth (as given above), only 56 per cent remained available for study during the entire 52 weeks' period. Because of the infrequency of twin births in the purebred Karakul flock, only lambs born as singles in all the breeds were studied. The Karakul and crossbred lambs resembled the Hampshire more than those of the other mutton breeds in size at birth. Birth weights of Karakul male lambs ranged from 9.3 to 12.8 and of females 6.3 to 12.8 pounds, an average of 11.1 and 10.2 pounds respectively. The crossbred female lambs averaged 10.3 pounds at birth. Karakul lambs were smaller than the Hampshire and larger than the Southdown lambs at any age. In rate of growth the Karakul and crossbred lambs showed greatest similarity to the Corriedale lambs, followed in order by the Shropshire, Southdown, and Hampshire breeds. The ability of purebred and crossbred Karakul lambs to grow at a rate comparable with those of some of the best mutton breeds is of economic importance to breeders who need to raise many of their lambs with inferior fur for meat purposes.

THE EFFICIENCY OF PHENOTHIAZINE SALT LICK AND DRENCH. W. T. S. Thorp and W. L. Henning, *Pennsylvania State College.*

During the past two years, a study has been made on the efficiency of phenothiazine when used as a drench and salt lick. Weekly parasite egg counts were made on each sheep used for the experimental work. Eighty-two sheep were included in this study; with 42 head, phenothiazine was given in various ways. Twenty Merino ewes were continued on a one to nine phenothiazine salt mixture throughout the winter of 1942–43. Blood counts and hemoglobin determinations were made at two-week intervals. These ewes were continued on this treatment during this last lambing season and throughout the summer of 1943, and included were ten of their lambs. In addition to the group of 20 Merino ewes and 10 lambs, four groups of 10 lambs each were given various treatments of phenothiazine. Another group consisted of 10 registered mutton ewes of three breeds and 10 lambs, in which case the ewes had been drenched the previous fall, and after lambing, but the lambs received no treatment. Another group of 10 lambs were left as a control group and did not receive any anthelmintic treatment,

some of which have died from parasites. Blood counts and hemoglobin determinations were made at two-week intervals. A summary of the weekly fecal counts, red and white blood cell counts, and the hemoglobin determinations is given in detail. Indications are that recommendations will consist of a combination program using the drench and the salt lick.

PHENOTHIAZINE AND SALT MIXTURE FOR SHEEP. R. J. Webb, E. H. Peterson, and W. G. Kammlade, *University of Illinois.*

A mixture of one pound of phenothiazine and fourteen pounds of salt reduced but did not eliminate parasites in a group of ewes and lambs (Lot 3). The mixture failed to satisfactorily control parasitic infestation in a group of ewes and lambs (Lot 2) grazing a pasture previously grazed by parasitized sheep (Lot 1) the same season. Although parasitism was not completely controlled in Lot 3, the general condition of the ewes and lambs was much better, and their gains in weight were considerably greater than in the other groups. The phenothiazine consumption on pasture was approximately 0.54 gram per head daily for all groups offered the mixture.

PHENOTHIAZINE FOR THE CONTROL OF STOMACH AND NODULAR WORMS IN SHEEP. John P. Willman and Donald W. Baker, *Cornell University.*

It has been satisfactorily demonstrated at the Cornell Agricultural Experiment Station and in field tests in New York State that phenothiazine is an effective therapeutic agent for the removal of the adult nodular worm in sheep. A control program which involves the use of phenothiazine given as a drench before the grazing season and after the sheep are brought in from pasture in the fall, combined with the use of a phenothiazine-salt lick during the pasture season should eventually bring nodular disease under control. Observations made this summer suggest that under the system of management followed at the experiment station and under the practices employed on general farms, eradication cannot be expected within the first year. Phenothiazine is quite effective when used as a drench for the removal of a large proportion of the trichostrongyle and strongyle worms inhabiting the abomasum and the small and the large intestines of sheep. The experiences of many farmers coincide with our observations that drenching with phenothiazine in the spring followed by an adequate supply of the phenothiazine-salt lick during the grazing season will not control the serious outbreaks of Hemonchosis, Trichostrongylosis and other forms of worm parasitisms encountered in the eastern states, when weather conditions are favorable to heavy exposures on permanent pastures. Several experienced purebred sheep breeders have tried to control parasites with the use of phenothiazine, but after suffering severe losses in midsummer were forced to return to the combined-sulfate treatment given as a drench at three- to four-week intervals.

THE EFFECT OF PREGNANT MARE SERUM IN THE ANESTROUS EWE. George W. Van Der Noot, Ralph P. Reece, and William C. Skelley, *New Jersey Agricultural Experiment Station.*

Attempts have been made to induce estrus in anestrous ewes by the injection of a gonadotropic hormone and to ascertain whether the ewes will conceive following this artificially induced estrus. On April 6, 1942, ten aged ewes were injected subcutaneously with 250 rat units of pregnant mare serum (Gonadin, supplied by Cutter Laboratories, through Dr. Donald H. Wonder) and one ram with 500 rat units of PMS. Estrus was not induced and the ewes were re-injected on April 22, 1942. Four days after the second injection some of the ewes showed signs of estrus, and within 10 days all of the ewes had mated. One of the ewes died on August 17 and an autopsy revealed that she was carrying a normal fetus. Five of the remaining ewes lambed (2 sets of twins and 3 single lambs) during the period of September 15 to October 4. The lambs were weaned in December, and the ewes came into estrus and mated. The 5 ewes lambed in the late spring of 1943. Twenty-five yearling ewe lambs were injected subcutaneously with 250 rat units of PMS on April 26, 1942. Eleven of the ewes came into estrus and mated within the following 10 days. The remaining 14 ewes were re-injected with 250 rat units of PMS 16 days after the first injection. Seven of these 14 ewes came into estrus

and mated. Five of the 25 ewes lambed (2 sets of twins and 3 single lambs) during the period of October 3 to October 20. These 5 ewes also lambed in the late spring of 1943.

Swine Section

Marvel L. Baker, *Chairman*

SINGLE WEIGHT VERSUS A THREE-DAY AVERAGE WEIGHT FOR SWINE. H. W. Bean, *University of Illinois.*

This discussion compares the first day weight with a simple arithmetic average of the weights obtained on three consecutive days. The data represent the initial and/or final experimental weights of approximately 3,300 pigs varying in size from 27 to 300 pounds. The deviation of the first day weight from the three-day average provides one standard of comparison. Light pigs from 27 to 39 pounds with a mean deviation of .33 pound show much less variation than the heavier weight of 180 to 219 pounds whose mean deviation is 1.71. The intermediate weight groups emphasize this tendency. The standard error serves as a second means of comparison. Three-day weights are not practical unless they are more reliable than a single weight. The fact that the number of weights is tripled indicates that the standard error of the averages should be equal to the standard error of the first-day weights divided by the square root of 3. In the lighter pigs there is little difference in the standard errors. This difference increases as the size of the animal increases. Statistical analysis does not justify three-day weights for pigs weighing less than 50 pounds. There appears to be some basis for weighing heavier pigs more than once.

CATTLE MANURE AND OTHER CARRIERS OF B-COMPLEX VITAMINS IN RATIONS FOR PIGS. G. Bohstedt, R. H. Grummer, and O. B. Ross, *University of Wisconsin.*

Practical swine rations that are balanced with only vegetable protein concentrates, and are fed in dry lot, are likely to be deficient in some of the B-complex as well as other vitamins. These deficiencies are to be expected if only the usual 5 per cent or less ground alfalfa hay is fed in the ration. In several dry-lot experiments with growing and fattening pigs, the yellow corn-soybean oil meal-5 per cent alfalfa meal-limestone-salt basal ration was supplemented with 2 per cent dried distillers' solubles, or 2 per cent dried brewers' yeast, or 10 per cent additional alfalfa meal, or free access to freshly collected cow manure. In some of the work, larger amounts of the distillery and brewery by-products were fed. On the basis of its favorable supplementary effect so far, and its relatively low cost, the use of dried distillers' solubles appears to have practical significance. As in numerous previous experiments, high-quality ground alfalfa hay, fed to the extent of 15 per cent of the ration, had such a good supplementary effect as to more than overcome the handicap of the increased amount of fiber. Such amounts of the hay increased the rate of gain in most cases, and lowered the cost of gain in all cases. A very interesting light is shed on the helpful supplementary effect of cattle manure which is not due to any whole undigested corn it may contain.

RELATION BETWEEN CARCASS CONFORMATION AND VALUE OF LIVE HOGS. G. E. Dickerson, Buford R. McClurg, and Fred J. Beard, *U. S. Department of Agriculture and Iowa State College.*

Data on 278 Poland China hogs slaughtered at approximately 225 pounds were analyzed to determine the relationship between carcass conformation and value per unit of live weight, as calculated from yields and prices of wholesale cuts. Measurements reflecting external conformation indicated differences in fat thickness and in length of bone and muscle rather than in muscle thickness; and hence were less accurate than measurements of muscling for predicting value. Width at the pelvic region and plumpness of ham were the only external measures indicative of muscle thickness. Hogs with deeper and wider carcasses and plumper hams were more valuable. Deeper carcasses yielded more ham and shoulder. Wider carcasses

yielded more belly and fat. Carcasses with plumper hams yielded more ham, belly and loin. Larger yields of loin and belly in longer carcasses were nearly offset by lower yields of fat and lighter hams. The best measure of muscling tried from wholesale cuts was area of lean (A) in the ham cross section calculated from ham circumference and thickness of ham fat. It was slightly superior to depth of lean on the ham and to a similar estimate (B) from the split carcass, using thickness of backfat instead of ham fat. Area of loin cross section indicated muscling and value more accurately than ham area (A), but required mutilation of the trimmed loin. Value increased with thickness of flank but not with depth of backfat; yields of belly and fat increased with both but smaller yields of lean were associated with thicker backfat.

PRELIMINARY RESULTS ON THE DISPENSABILITY OF ANIMAL PROTEIN IN CERTAIN SWINE RATIONS. N. R. Ellis and J. H. Zeller, *United States Department of Agriculture, Washington, D. C.*

A comparison has been made of diets with and without animal protein for reproduction and growth in swine. Four groups each of sows and gilts were fed throughout the gestation period in the winter of 1942–1943 and corresponding groups in the summer of 1943 on diets of (a) corn and trinity mixture, (b) corn and vegetable-protein mixture, (c) wheat and vegetable-protein mixture, and (d) corn and low animal-high vegetable protein mixture. The animals also had access to legume hay during the winter season and grazed on pasture during the summer. No marked differences attributable to diet were observed in the pig crop. Of those litters of the spring farrow which remained on the diets, the ones on diet (b) appeared to be somewhat retarded in growth not only when weaned but throughout the growing and fattening period. These preliminary results indicate that a good all-vegetable-source diet can be used during the gestation period but is less satisfactory for the rapid growth and development of growing pigs than a diet containing some animal protein. Furthermore, wheat has proven more satisfactory than corn with the all-vegetable-protein supplement which was used.

AN ATTEMPT TO IMPROVE A CONCENTRATE MIXTURE COMPOSED OF YELLOW CORN, BEEF MEAL, SOYBEAN MEAL AND ALFALFA MEAL FOR WEANLING PIGS IN DRYLOT. B. W. Fairbanks, W. E. Carroll, T. A. King, J. L. Gobble and J. L. Krider, *Illinois Agricultural Experiment Station.*

Two experiments in which 148 head of 30-pound weanling pigs were fed to a final weight of 75 pounds are reported. A basal concentrate mixture of ground yellow corn, beef meal, soybean meal, alfalfa meal, and salt was compared with the basal ration plus either hulled oats, dry skimmilk, or dried corn distillers' solubles. The data indicate that hulled oats contributed to the nutritive qualities of the basal mixture. The mixture containing hulled oats produced significantly more rapid daily gains and more economical gains than the basal mixture. The addition of the amounts of dry skimmilk and dried corn distillers' solubles fed in these tests did not improve the nutritive properties of the basal concentrate mixture.

BREEDING FOR RATE OF GAIN WITH SWINE. A PROGRESS REPORT. B. W. Fairbanks, Elmer Roberts, and W. E. Carroll, *Illinois Agricultural Experiment Station in Cooperation with Regional Swine Breeding Laboratory.*

From a random population of registered Hampshire swine, selection based on weight for age has been made through three generations for rapid-gaining and slow-gaining strains. The foundation animals for the two strains were selected on the basis of weight at 180 days of age from 41 head of Hampshire boar pigs and 42 head of Hampshire sow pigs from the 1939 spring farrow of 48 Illinois Hampshire herds. The five most rapid gaining boars and 15 most rapid gaining sows, and a like number of the slowest gaining boars and sows were selected as the foundation herds. Two lines have been established. The differences in the average weight of the pigs between lines by generations are: First generation, 14.0 pounds; second generation, 9.5 pounds; and third generation, 32.3 pounds. The difference between lines is largely due to a decline in gaining ability of the slow-gaining strain rather than to improvement in the rapid-gaining strain. The weight data indicate that selection on the basis of gain

has had little or no effect on milking ability. There has been a parallel decrease in average litter size in both lines, which explains the noted increase in the birth weight of the pigs during the three generations. Body measurements have been taken at 200 pounds. The pigs of the slow-gaining strain are longer in body but not as deep as the rapid-gaining strain.

LOCOMOTOR INCOORDINATION IN PIGS FED "GOOD" RATIONS. L. E. Hanson, *Nebraska Agricultural Experiment Station.*

Pigs farrowed in drylot and placed on "good" rations in lots with concrete floors, at initial weights of 41 to 70 pounds, developed various degrees of unthriftiness and locomotor incoordination of the rear limbs. The rations fed included: (1) A mixture of white corn, tankage, soybean meal and forage. (2) A mixture of yellow corn, 5 per cent artificially dried alfalfa meal or ground field-cured alfalfa hay, and a supplement composed of equal parts by weight of tankage, sardine meal, soybean meal, and linseed meal. Notable unthriftiness or incoordination occurred when the pigs were from 118 to 178 days of age. Some pigs developed incoordination but continued to make good gains, others became very unthrifty without losing their coordination. An abnormal skin condition was present in most of the pigs in two trials conducted during the winter of 1942–43. Type 2019, non-irradiated dry yeast (Standard Brands) fed at a level of 0.3 pound daily resulted in a marked improvement of appetite and rate of gain, and in some improvement in coordination in one pig. Strain G., Brewers' type yeast (Anheuser-Busch) fed at a level of 0.2 pound daily resulted in a remarkable increase in growth rate, improvement in condition, and coordination in one pig. Increasing the alfalfa from a 5 per cent level to a 10 per cent level in one trial appeared to be beneficial. A few pigs given a supplement of cod-liver oil and placed in a separate lot in which they had access to dirt improved markedly in growth rate.

HERITABILITY OF TYPE IN POLAND CHINA SWINE AS EVALUATED BY SCORING. H. O. Hetzer and J. H. Zeller, *U. S. Department of Agriculture.*

Data were analyzed to determine the heritability of variations in the type of Poland-China pigs measured by a scoring scheme used at the Beltsville Research Center. Type was evaluated by scores ranging from 1 to 9, 1 and 3, 4 and 6, and 7 and 9 representing the high and low thirds of large, intermediate and small type scores respectively. The 731 pigs were farrowed in 210 litters out of 111 sows by 32 boars during 14 separate seasons. The method used was correlation between paternal half-sibs since only a few dams were awarded type scores comparable to those of their offspring. The intra-type variance between contemporary litters by the same sire was 8.0 per cent less than the total variance which would have existed in a population of litters all from different dams and each by a different sire. This corresponds to an intra-type correlation of 0.08 between paternal half-sibs born during the same season and might be expected to consist of about one-fourth of the additive genetic fraction of the variance plus a small part of the variance due to epistatic and environmental correlations. Since at best only about one-sixteenth of the correlation would be due to epistatic interactions and since the environmental correlation between paternal half-sibs in these data probably was close to 0, multiplying 0.08 by 4 yields 0.32 as the additive genetic fraction of the variance. This estimate does not include whatever genetic differences there were between herds and probably is a little smaller than it would have been in a population in which there had been more intense selection towards either extreme. It seems reasonable to conclude that at least 30 per cent of the individual variance in type was due to the additive effects of genes.

THE RELATIONSHIP BETWEEN GROWTH RATE AND CARCASS MEASUREMENTS IN SWINE. L. N. Hazel, C. F. Reinmiller and Marvel L. Baker, *Nebraska Agricultural Experiment Station and United States Department of Agriculture.*

The relationship between growth rate and eight carcass measurements (market grade, length of body, depth of body, ham index, thickness of shoulder, flank, ham and backfat) were studied on 152 barrows which had been self-fed a standard feed mixture and reared under reasonably uniform conditions. The barrows averaged 225 pounds and had a standard devia-

tion of 6.8 pounds in live weight when slaughtered. The correlations between final market weight and carcass measurements varied from .18 to .32 except for thickness of flank where it was practically zero. The partial correlations (with final weight constant) between 180 day weight and depth of body, ham index and thickness of backfat were −.17, .23 and −.18 respectively. The correlations involving 180-day weight and the other measurements were smaller and without statistical significance. The growing period was subdivided into three intervals to determine whether growth rate at different ages had any consistent or progressive influence upon carcass measurements. The correlations for the different intervals were not very consistent and did not indicate progressive changes, being for the most part small and insignificant. From these results it seems that carcass conformation can be changed only slightly by varying growth rate over the range observed in this study ($\sigma = 28.8$ pounds for 180-day weight). There is little to be gained in genetic or nutritional studies by eliminating that portion of the variation in carcass measurements which can be attributed to the observed variation in growth rate.

PLANT PROTEIN CONCENTRATES FOR PIGS. W. L. Robison, *Ohio Agricultural Experiment Station.*

The scarcity of animal protein concentrates has made it necessary, contrary to former common practice, to rely largely or wholly on protein concentrates of plant origin in growing and fattening rations for pigs. Since it is produced in the area and is available in relatively large quantities, soybean oil meal is the plant protein concentrate which is used most extensively and is of chief concern in the corn belt where hogs are the most numerous. In trials on pasture, pigs fed roasted nut-like soybean oil meal made faster gains and required only a little more feed per unit of gain than similar pigs fed tankage. Both rations were fortified with minerals. When fed with yellow corn, ground alfalfa, and minerals to pigs in drylot, roasted nut-like soybean oil meal produced somewhat slower gains but as much gain per unit of feed and as economical gains as a mixture of tankage and linseed meal. A larger percentage of the pigs became unthrifty, suggesting a deficiency in the ration in one or more respects. In what way or ways such a ration is deficient has not been definitely established. Fish meal was an effective corective but little of it is now available. Tankage was less effective but of some benefit. Materials being tried with yellow corn, soybean oil meal, ground alfalfa, and minerals and to be reported on are oats, tankage, soybean oil, dried brewers' yeast, growing yeast, and a mixture of linseed and cottonseed meal.

Teaching and Extension Section

F. L. Bentley and H. G. Zavoral, *Co-chairmen*

FUNDAMENTALS IN ANIMAL HUSBANDRY AND SPECIFIC PROGRAMS OF LIVESTOCK ENTERPRISE FOR POSTWAR AGRICULTURAL STUDENTS. James F. Fuller, *Madison, Wisconsin.*

On considering the subject of training for postwar students attending agricultural colleges, in addition to those who enter regular prescribed courses and qualify for a degree, there will be the adult specials who seek training for the purpose of earning a living. To provide a program of suitable courses and subject matter for these special students will require careful thought and planning. Fundamentals in every subject must be given thoroughly and fully understood by the student. In animal husbandry, they should include the function of livestock in farms, areas of livestock production in the United States, terms, definitions, reasons for fattening livestock, and milk production, labor, skill, etc. The training of special students of the vocational type must include a high proportion of laboratory work. Assisting in the manual work with feeding trials in progress can be of great value to the student. Supervision of the vocational or laboratory work should provide a definite program of planned exercise, reported and summarized by the students. From some source, either from his work in animal husbandry, or from working in farm management, the student should be given study

of the annual program followed on various types of livestock farms. The postwar special student in agriculture may be enrolled in many of the regular university or college courses, but in addition, special laboratory work and vocational training should be arranged to best meet the need of that type of student.

THE EVOLUTION OF A PROFESSOR. V. A. Rice, *Massachusetts State College.*

A plea for more original and inspired teaching in Animal Husbandry classrooms. The writer severely criticizes the usual textbook and lecture methods, and outlines a plan for greater student participation. Too many teachers try to hand out ready made segments of education to a supposedly "hungry for learning" body of students. The writer's plea is for a changed viewpoint on the whole process of education based upon the fundamental truth that "The only education worthwhile is self-education."

BEEF CATTLE DEVELOPMENT IN THE SOUTHEASTERN STATES. A. L. Shealy, *University of Florida Agricultural Extension Service.*

With the advent of the boll weevil two decades ago and the relative low price received for cotton, farmers in the southeast have turned to livestock in diversifying their farms. Many of the crops planted in the soil conservation program were feed crops for livestock. Over two million acres of improved pastures have been developed within this section during the past ten years. These pastures include such grasses as carpet, Bermuda, Dallis, and Bahia. Through proper fertilization, which includes the use of lime and phosphate, thousands of acres of legume pastures have been established. Following tick eradication, numerous purebred bulls of the Hereford, Aberdeen Angus, Shorthorn and Brahman breeds were shipped into the southeast from herds in the southwest and midwest. These bulls have been bred to native cows with the result that the offspring show distinctly beef characteristics, thereby improving the grade. The number of beef cattle in the southeast has increased 22 per cent during the past 10 years, while the country as a whole shows an increase of 15 per cent. Four large meat packers have plants in the southeast and numerous small killing plants have been established. These plants provide a steady market for livestock. There are numerous auction markets that afford a channel of marketing any class and grade of cattle in communities that would not be served by the packing houses and smaller killing plants.

NEWS AND NOTES

The Annual Meeting of the American Society of Animal Production will be held at the Hotel Sherman in Chicago, on Tuesday, November 30 and Wednesday, December 1, 1943. Abstracts of papers to be presented in the various sectional meetings appear in this issue of the JOURNAL. The programs of the general sessions will be devoted to discussions of the ways in which animal husbandry work can best serve the war effort and the adjustments that will have to be made in the post-war period.

It should be noted that at the 1942 business meeting of the Society unanimous approval was given to the recommendation of the Executive Committee that at the 1943 Annual Meeting a registration fee of fifty cents per person be charged.

The nominating committee composed of Professors Jay L. Lush, G. H. Hart, and G. Bohsted present the following slate of nominees for consideration of the Society:

President, L. A. Weaver
Vice-President, A. D. Weber
Secretary-Treasurer,
W. V. Lambert
W. C. Kammlade

Additional nominations may be made from the floor at the Annual Meeting before the nominations are closed for ballot. For details of procedure in the election of officers see JOURNAL OF ANIMAL SCIENCE, Vol. 2, No. 1, February, 1943, pages 96–97.

Dr. L. A. Maynard, President of the American Society of Animal Production, has a communication from Dr. Ralph Phillips, Editor of the JOURNAL OF ANIMAL SCIENCE, reading in part as follows:

"I trust that all goes well with The American Society of Animal Production affairs, and particularly with the JOURNAL OF ANIMAL SCIENCE. One develops a very definite feeling of isolation in this country, even in Chungking, and especially in the inner-Asian frontier. There is much of interest to be seen on all sides, and much to be done here in the field of animal industry in all of its phases."

A recent book by one of the Society's members, Frank G. Ashbrook, is, "How to Raise Rabbits for Food and Fur" (Orange Judd Publishing Co., N. Y., 1943, $2.00). It is clearly presented, thorough in practical information, well illustrated and indexed. The presentation on construction of housing is an outstanding feature of the book that will give it permanent value. Rabbit raisers, especially the large army of victory rabbitteers, and those persons who are interested in stretching their meat ration points, will find the book answers their questions including such final items as how to cook the meat and what to do with the fur.

W. F. Lamoureux of Cornell, M. A. Jull of Maryland, and J. L. Lush of Iowa, spent several weeks this summer at the Kimber Poultry Breeding Farm, Niles, California, in conference on breeding problems and plans.

E. W. Warwick, formerly of Texas A & M College, has recently completed work for the Ph.D. degree at the University of Wisconsin and is now an instructor in Animal Husbandry at Washington State College.

A. Kirk Besley, of the Meat Section of the Animal Husbandry Division of BAI, has resigned to accept appointment as superintendent of the new Prince Georges County (Maryland) Hospital.

M. A. McCarty, Associate Professor Animal Husbandry, Pennsylvania State College, resigned in June to go into farming with his brother in Minnesota.

S. S. Wheeler, of the University of Wyoming, Animal Husbandry staff, and Rufus S. Cox, of the same staff of the Kansas State College, are now on temporary detail with the Food Distribution Administration.

Jerry Sotola, of the Animal Husbandry staff of the Washington State College, has resigned to join the research division of Philip R. Park, Inc., San Pedro, California.

Fred Miller, of N. C. State College and Secretary of the Southern Agriculture Workers Association, was seriously injured in an automobile accident on June 22.

E. A. Trowbridge, Head of the Animal Husbandry Department, University of Missouri, judged the Junior League Horse Show recently held at Lexington, Kentucky.

A. C. Mowery, Instructor in Animal Husbandry at the University of Arkansas, has resigned.

George R. Johnson took up full time extension work with emphasis on sheep production at Cornell University on July 1, 1943.

O. Burr Ross, of the Animal Husbandry staff, University of Wisconsin, is now on military leave with the Army of the United States.

Kenneth A. Clark, formerly of the University of Maryland and more recently with a feed concern at Frederick, Maryland, is now with the S & K Packing Company, at Baltimore.

John T. Caine, III, of the Chicago Union Stock Yards Company and Assistant Manager of the International Livestock Exposition, has resigned to become manager of the National Western Stock Show at Denver and Public Relations representative of the Denver Livestock Exchange and the Denver Union Stock Yards Company.

Louis H. Rochford, Extension Animal Husbandman, University of California, resigned July 1 to become resident manager of the El Tejon Ranch near Bakersfield, California.

Allen E. Bogue, formerly of the Animal Husbandry staff of the University of Maryland and more recently with the Chicago Producers Livestock Commission Company, has joined the nation's armed forces.

H. B. Osland, formerly head of the Animal Husbandry Department, Colorado State College, is now operations supervisor of the Baca Grant Ranch at Crestine, Colorado.

H. H. Smith, for many years a member of the Animal Husbandry staff, as Livestock Extension Specialist, Utah Agriculture College, has succeeded A. C. Allen, as Extension Animal Husbandman, Colorado State College.

J. O. Bridges, Associate Professor Animal Husbandry and Associate Animal Husbandman at the New Mexico Agriculture College, has resigned to go into livestock farming in Idaho.

Carl A. Olsen, field repreeentative of the Iowa Beef Producers Association at Ames, was appointed field representative of the American Aberdeen Angus Breeders Association, effective July 15.

A. C. Allen, Extension Animal Husbandman, Colorado State College, resigned to take charge of the registered Hereford Cattle and the sheep on the Hatchett Cattle Company's 3R ranch, near Pueblo, Colorado.

Frank W. Farley, after 24 years association with the American Hereford Journal, resigned June 30 to become publisher of the Southern Stockman, Memphis, Tennessee, vice his son who had joined the armed forces.

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